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VOL. 170 PART I

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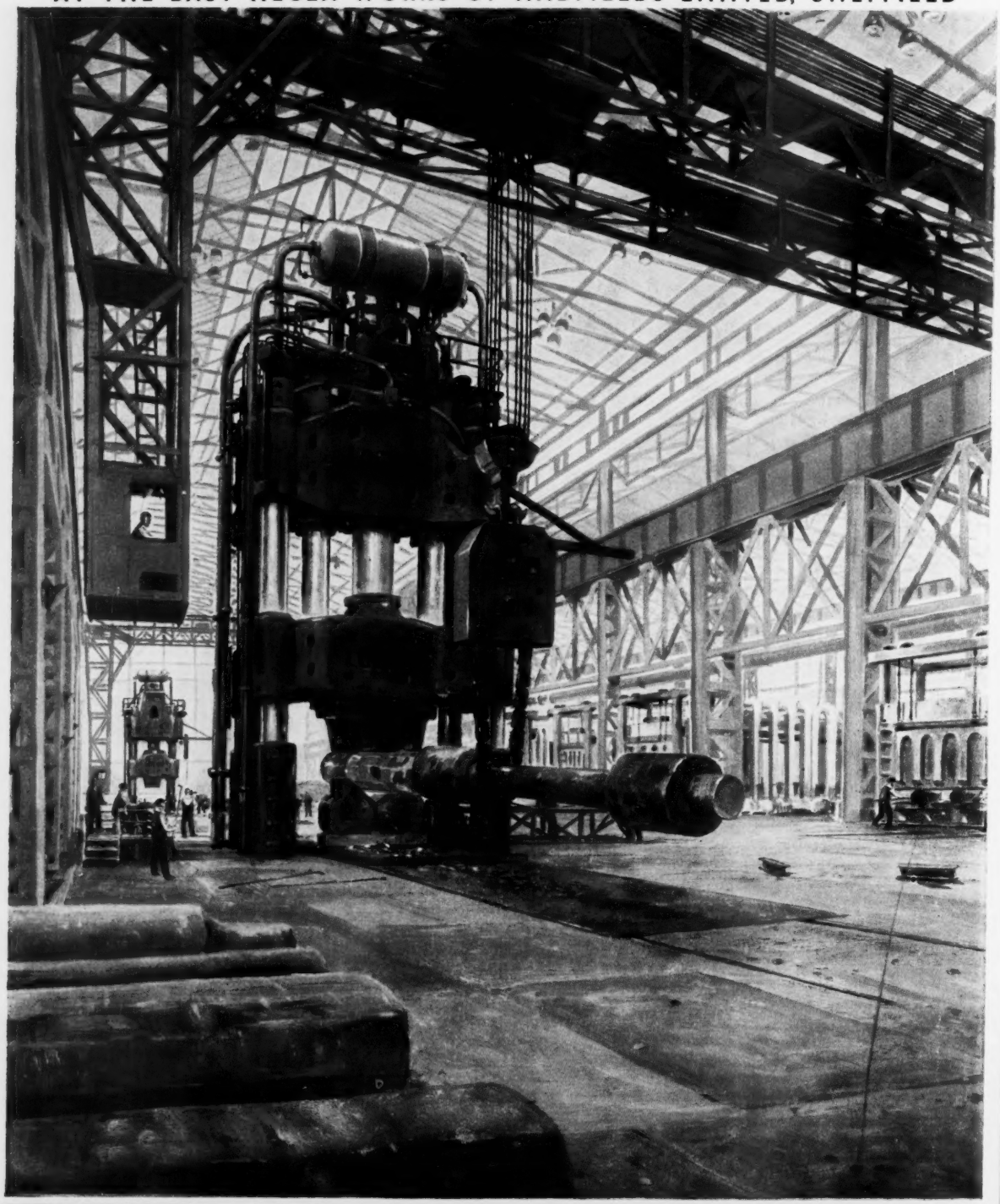

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ABBREVIATIONS AND SYMBOLS

A.	Ångstrom unit(s) = 1×10^{-10} m.
A.C.	air-cooled; alternating current
A.H.	air-hardened
amp.	ampère(s)
amp.hr.	ampère-hour(s)
approx.	approximately
at.-%	atomic per cent
at.wt.	atomic weight
atm.	atmosphere(s) (pressure)
A.W.G.	American wire-gauge
° Bé.	Baumé (degree)
b.h.p.	brake horse-power
B. & S.	Brown and Sharpe (gauge)
B.o.T.	Board of Trade
b.p.	boiling point
B.T.U.	Board of Trade unit(s)
B.Th.U.	British thermal unit(s)
B.W.G.	Birmingham wire-gauge
° C.	centigrade; Celsius (degree)
cal.	calorie(s)
c.c.	cubic centimetre(s)
c.d.	current density
c.g.s.	centimetre-gramme-second unit(s)
cm.	centimetre(s)
coeff.	coefficient(s)
conc.	concentrated
const.	constant(s)
cu.	cubic
cwt.	hundredweight(s)
D.C.	direct current
dia.	diameter
dil.	dilute
dm.	decimetre(s)
e.m.f.	electromotive force
e.v.	electron volt(s)
° F.	Fahrenheit (degree)
ft.	foot, feet
ft.lb.	foot-pound(s)
g.	gramme(s)
gal.	gallon(s)
H.F.	high-frequency
h.p.	horse-power
h.p.hr.	horse-power-hour(s)
hr.	hour(s)
in.	inch(es)
in.lb.	inch-pound(s)
I.S.W.G.	Imperial standard wire-gauge
° K.	absolute temperature (Kelvin scale)
kg.	kilogramme(s)
kg.cal.	kilogramme-calorie(s)
kg.m.	kilogramme-metre(s)
km.	kilometre(s)
kV.	kilovolt(s)
kVA.	kilovolt-ampère(s)
kW.	kilowatt(s)
kWh.	kilowatt-hour(s)
kX.	crystal Ångstrom(s) = 1000 Siegbahn X-units

l.	litre(s)
lb.	pound(s)
L.F.	low-frequency
M	molar (solution)
m.	metre(s)
m.amp.	milliampère(s)
max.	maximum
mg.	milligramme(s)
min.	minimum; minute(s)
ml.	millilitre(s)
mm.	millimetre(s)
m.m.f.	magnetomotive force
m.p.	melting point
mV.	millivolt(s)
mμ	millimicron = 1×10^{-9} m. = 10 Å.
N	normal (solution)
N.T.P.	normal temperature and pressure
O.H.	open-hearth; oil-hardened
O.Q.	oil-quenched
oz.	ounce(s)
p.d.	potential difference
*p*H	hydrogen-ion concentration
p.p.m.	parts per million
r.p.m.	revolutions per minute
sec.	second(s)
sp.gr.	specific gravity
sq.	square
S.W.G.	standard wire-gauge
T.	tempered
temp.	temperature
V.	volt(s)
VA.	volt-ampère(s)
W.	watt(s)
Wh.	watt-hour(s)
W.G.	water-gauge
W.Q.	water-quenched
wt.	weight
wt.-%	weight per cent
yd.	yard(s)
μ	micron(s) = 1×10^{-6} m.
μg.	microgramme(s) = 1×10^{-6} g.
μμ	1 millionth micron = 1×10^{-12} m. = 0·01 Å.
Ω	ohm(s)
°	degree (arc or temperature)
′	minute of arc; foot (feet)
″	second of arc; inch(es)
$<$	less than
$>$	greater than
$\not<$	not less than
$\not>$	not greater than
$\leqslant$	equal to or less than
$\geqslant$	equal to or greater than
$\neq$	not equal to
$\equiv$	identically equal to
$\simeq$	approximately equal to
$\propto$	proportional to

Unless otherwise stated above, the symbols given in the following British Standards are used in the *Journal:* Chemical, Thermodynamical, and Physico-chemical quantities: B.S. 813; Engineering units: B.S. 560.

G. H. JOHNSON, M.I.Mech.E., F.I.M.

GEORGE HENRY JOHNSON was born and educated at Middlesbrough. He qualified in Iron and Steel Manufacture and Metallurgy under the City and Guilds of London Institute, and trained for a metallurgical career at the Acklam Iron and Steel Works of Dorman Long and Company, Limited.

After service as Works Manager of The Kettering Iron and Coal Company, Limited, he was appointed General Manager, and since 1931 has been Managing Director of the Company. He is a Member of the Executive of The Joint Iron Council and a past Chairman of the Foundry Pig Iron Producers' Association. Mr. Johnson joined the Board of British Benzol and Coal Distillation, Limited, Bedwas, Mon., in 1941, and in 1944 he was elected Chairman.

Of recent years, executive and administrative duties have claimed a good deal of Mr. Johnson's time, but his keen interest in research never diminished and, on the formation of the British Iron and Steel Research Association, he became the first Chairman of the Iron Making Division and served in that capacity until last year. He is now a Member of Council of the British Iron and Steel Research Association and of the British Cast Iron Research Association. For many years he has been Chairman of the Blast Furnace Refractories Joint Committee.

In local affairs, Mr. Johnson served as a Member of the Northamptonshire County Council for nine years, and in his early years he played first-class cricket for the County and was awarded his cap.

He was elected an Associate Member of the Institution of Mechanical Engineers in 1927 and became a Member in 1943. He is also a Fellow of the Institution of Metallurgists. Mr. Johnson became a Member of The Iron and Steel Institute in 1924 and was elected a Member of Council in 1950.

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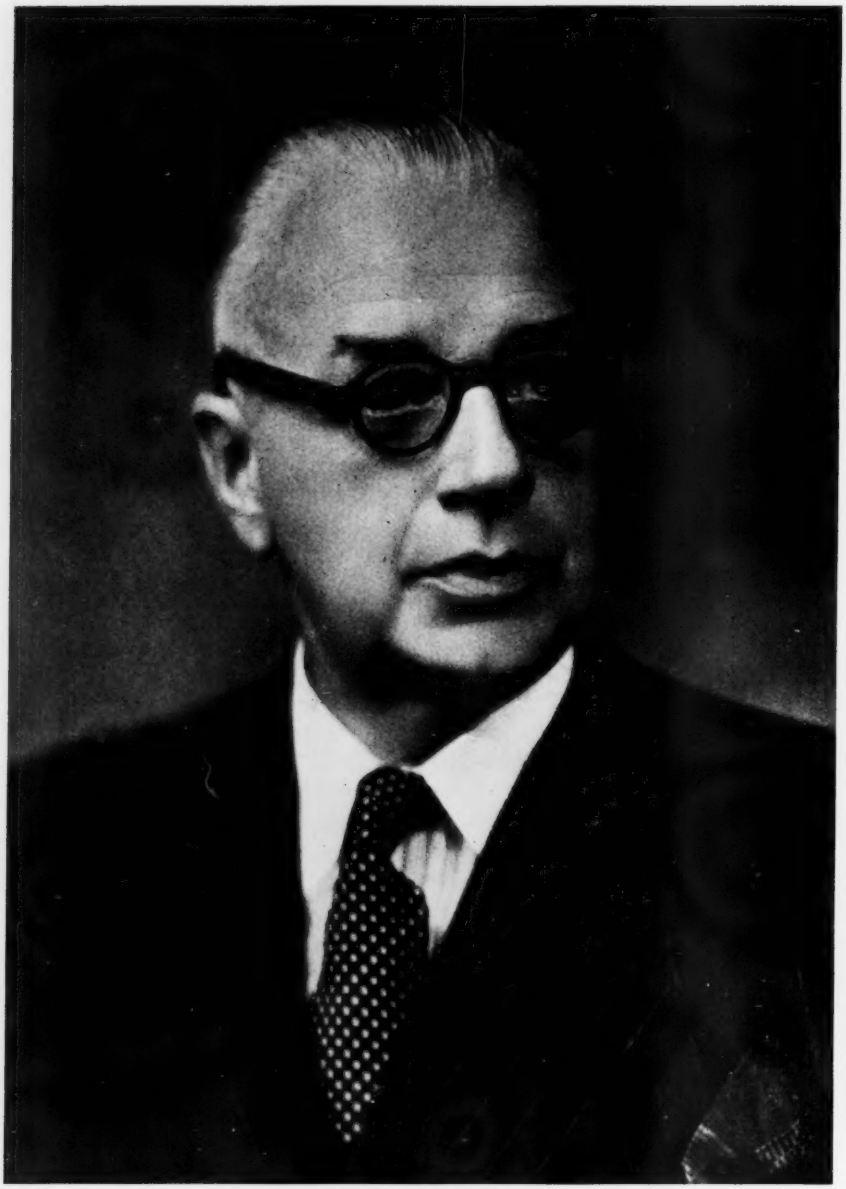

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IRON AND STEEL
INSTITUTE PAPERS

PLANT DESIGN · MANUFACTURE · RESEARCH · DEVELOPMENT

Effect of Alloying Elements on the Breakdown of Austenite at Sub-Zero Temperatures—Part I

By J. O. Ward, A.Met., A.I.M., M. D. Jepson, M.Sc., Ph.D., and J. R. Rait, Ph.D., D.Sc., A.R.T.C., F.I.M.

SYNOPSIS

The first part of a systematic study of the effects of alloying elements on the transformation of austenite by refrigeration is described.

In the preliminary experiments, using a 1% carbon–0·3% manganese base material, up to 3–4% of manganese, chromium, and nickel was added separately. The amount of sub-zero transformation was increased by manganese and nickel, but, although increasing at first with the addition of chromium, fell off at more than 1% of chromium.

The full survey has been started by observing the effect of up to 10% of manganese on the retention of austenite during the quench and on the stability of this austenite to sub-zero breakdown.

Introduction

Most of the published work concerned with sub-zero transformation has come from two groups of workers, Gulyaev in the U.S.S.R. and Cohen and his associates in the U.S.A. In 1937, Gulyaev[1] gave some information on the extent of sub-zero transformation of high-speed steel and on the behaviour of treated tools in service. Later, he reported work[2] on other types of steel, and summarized his results as follows :

(1) Sub-zero treatment of a steel containing retained austenite causes some of the austenite to transform to martensite

(2) If accompanied by transformation, sub-zero treatment leads to an increase in volume, in magnetic induction, and in hardness

(3) With most steels, cooling to − 183° C. is not sufficient to transform all the retained austenite

(4) A sub-zero treatment becomes increasingly effective the sooner it is applied after quenching

(5) The temperature of commencement of transformation is depressed by increasing the time interval between quenching and sub-zero cooling.

Cohen[3–13] found that the breakdown of austenite to martensite, and hence the quantity and stability of any austenite retained on quenching to room temperature, depends on :

(i) The austenitizing temperature. The higher the austenitizing temperature, the greater the quantity of austenite retained

(ii) The grain size. The larger the grain size, the less austenite is retained

(iii) Ageing. Holding at room temperature, or at any temperature below M_s, increases the amount of austenite retained on subsequent cooling. The effect depends on time and temperature

(iv) Quenching rate. In some steels in which stabilization is of major importance, the rate of cooling has the effect that the slower the rate (greater than the critical), the more austenite is retained.

The breakdown is self-stopping and ceases with some austenite untransformed, the amount varying with the steel composition, from less than 1% in, say, a 0·2% C steel to 100% in 13% Mn – 1·2% C steel. These conclusions are additional to those reached by Gulyaev, which have also been confirmed. Cohen's explanation, based on thermodynamic considerations,[14] postulates the existence of nuclei (elsewhere[13] identified as screw dislocations) from which an accumulation of energy, produced by cooling, enables shear to be propagated. The increase, or decrease, in the numbers of nuclei is considered to determine whether a particular treatment renders the austenite more unstable, or causes stabilization, respectively.

In the work reviewed above there is a very significant gap, in that no attempt has been made to investigate systematically the effects of various common alloying elements on the amount and stability of the austenite retained on quenching. Investigations were therefore carried out on a basic 1% C – 0·3% Mn steel, to which were added various amounts of one

Manuscript received 18th August, 1950.

Mr. Ward and Dr. Jepson are on the staff of the Research Department of Messrs. Hadfields, Ltd., Sheffield. Dr. Rait is a Local Director of Messrs. Hadfields, Ltd.

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other alloying element at a time, starting with manganese, nickel, and chromium.

This first part of the survey covers alloys containing up to 2·5% of manganese, 3·5% of chromium, or 4·5% of nickel, which enabled a technique to be established and indicated the trends to be expected. The first part of the main investigation, a study of a series of manganese steels on the 1% C base, up to 10% of manganese, is also reported. The second part of the main programme, the study of steels containing up to 10% (and probably 15%) of chromium or nickel, has been started and will form Part II. The theoretical discussion of the results is left to subsequent papers.

PRELIMINARY SURVEY

Material and Specimen Preparation

The alloys used in this preliminary work were melted in a small high-frequency furnace, and 4-lb. aluminium-killed ingots were cast. The compositions of the various steels are given in Table I.

The ingots were forged down to $\frac{5}{16}$-in. dia. rods, which were cut into lengths before being packed in cast-iron turnings and given a homogenizing treatment of 10 min. at 1050° C. followed by cooling (still packed in the turnings) in air. The specimen size adopted, *i.e.*, 5 mm. dia. × 65 mm. long, is standard in this laboratory, for most tests. The large machining allowance ensured the absence of decarburized material in the test specimens, which were nickel-plated to a depth of 0·005 in. before testing.

Apparatus and Technique

All treatments were carried out with the specimen mounted in a trifilar dilatometer similar to the type developed by The United Steel Companies' laboratories for isothermal work. The dilatometer (Fig. 1) was modified by increasing the length and thickness of the trifilar members, and a Mercer dial gauge measuring to 0·0001 in. was substituted for the more usual 0·001 in. gauge. To avoid any sticking in the action of the dilatometer or gauge, a reed was fixed to the dilatometer head and was vibrated at 50 cycles/sec. by an electromagnet, a magnet coil being placed at each of the points on which the dilatometer would rest during the various treatments. This device was found to improve the reproducibility of the results, particularly when only small changes, of the order of 0·0005 in. dilatation, were involved.

The specimen was bedded in the dilatometer, which was then placed in a furnace held at 900° C. provided

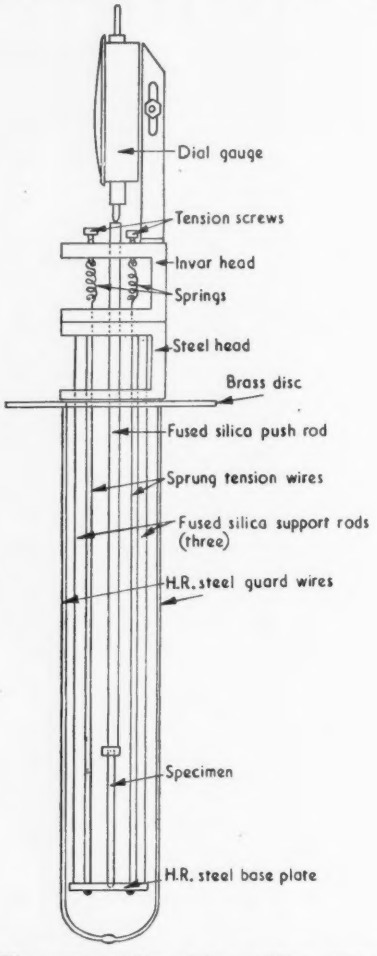

Fig. 1—The construction of the trifilar dilatometers (approximately to scale)

Table I

ANALYSES OF STEELS USED IN PRELIMINARY SURVEY

Steel*	C, %	Si, %	S, %	P, %	Mn, %	Cr, %	Ni, %	Mo, %	Cu, %	W, %	Co, %
01020 *A*	0·99	0·11	0·009	0·036	0·30	0·01	0·02	0·02	0·03	Nil	...
01020 *B*	1·04	0·14	0·006	0·040	1·02	0·01	0·02	0·02	0·03	Nil	...
01020 *D*	1·06	0·16	0·010	0·040	1·56	0·02	0·02	0·02	0·03	Nil	...
01020 *E*	1·05	0·17	0·008	0·040	2·35	0·03	0·02	0·02	0·03	Nil	...
01021 *F*	0·96	0·17	0·010	0·038	0·30	0·48	0·02	0·03	0·02	Nil	...
01021 *G*	0·96	0·16	0·010	0·036	0·31	1·10	0·02	0·03	0·02	Nil	...
01021 *H*	1·11	0·20	0·009	0·036	0·30	2·34	0·02	0·03	0·02	Nil	...
01021 *I*	1·20	0·26	0·009	0·034	0·36	3·98	0·02	0·03	0·02	Nil	...
01022 *J*	0·95	0·16	0·012	0·018	0·32	0·01	0·48	0·03	0·03	0·03	...
01022 *K*	0·94	0·18	0·011	0·016	0·31	0·01	1·03	0·03	0·03	Nil	...
01022 *L*	0·88	0·19	0·013	0·019	0·30	0·01	2·41	0·03	0·03	Nil	...
01022 *M*	0·86	0·19	0·012	0·019	0·30	0·01	4·48	0·02	0·03	0·03	0·03

* The steels contained no vanadium

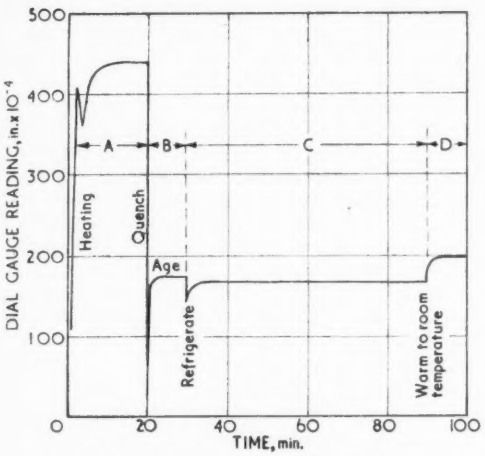

Fig. 2—Idealized dilatometer record

with a dry nitrogen atmosphere. The combination of this and the nickel plate was found to be completely successful in eliminating decarburization. The specimen reached temperature in about 5 min. and was then soaked for 15 min. before quenching in water-cooled stirred oil. The specimen was held in the oil for 1 min., drained for 10 sec., and then rinsed in trichlorethylene for 20 sec. A final 30-sec. drying by an air blast made the minimum time interval between hardening and refrigeration equal to 2 min.

The efficiency of the oil quench was checked by examining the microstructures of specimens of the low-alloy steels in the quenched condition. In no case was any sign of a high-temperature transformation product observed, the structures consisting entirely of austenite and martensite.

Time intervals of 2 min., 10 min., 100 min. (1 hr. 40 min.), 1000 min. (16 hr. 10 min.), and 10,000 min. (6 days, 22 hr., 40 min.) were employed. After the appropriate interval the specimen was immersed in a bath of standard pentane, which contained an excess of solid carbon dioxide (*see* Appendix). The specimen was soaked at — 78° C. for 1 hr.; this time was fixed to standardize the treatment, although no evidence has been obtained that the time at this temperature has any effect, provided it is sufficiently long for the whole of the specimen to have reached the bath temperature.

The dilatation results were of the form shown by the curves plotted in Fig. 2, which can be divided into four parts:

A. Heating and soaking, thermal expansion, and A_1 transformation
B. Quenching, thermal contraction, and martensite expansion
C. Sub-zero cooling, thermal contraction, and further martensite expansion (if any)
D. Warming to room temperature—thermal expansion.

The increased breakdown of austenite due to sub-zero treatment is indicated by the increase in length of the specimen, at room temperature, over and above the length just before immersion in the sub-zero bath. This 'dilatation due to sub-zero treatment' has been taken as one measure of the amount of transformation taking place during cooling between atmospheric temperature and — 78° C. The other method used to determine the extent of the sub-zero transformation involved the measurement of the specific magnetism of the specimens at various stages during the treatment. The specific magnetism of a material is the ratio of the *B–H* value for the specimen to the value of *B–H* for pure iron at the same field strength *H*. The field strength should be such that both the specimen and the standard are saturated or nearly so. The standard used was of re-melted electrolytic iron, or Swedish charcoal iron, more than 99·9% pure. Measurements were made with a modified Fahy permeameter at field strengths of over 2000 Oersteds. Each specimen was tested in the homogenized and in the treated conditions; also, where possible (*i.e.*, in the 100-min. or greater time intervals) they were tested in the as-quenched condition. An average value of the readings taken on the as-quenched specimens of each steel was used for calculations. Considering

Table II

DILATATION AND SPECIFIC MAGNETISM RESULTS OF PRELIMINARY SURVEY

Steel	Alloy Addition	Average Dilatation (× 0·0001 in.) at Time After Treatment					Average Specific Magnetism (%) at Time After Treatment					
		2 min.	10 min.	100 min.	1000 min.	10,000 min.	As Quenched	2 min.	10 min.	100 min.	1000 min.	10,000 min.
01020*A*	0·3% Mn	29·4	26·2	16·5	9·9	<1	81·9	91·5	91·1	90·0	86·6	81·7
01020*B*	1·0% Mn	41·5	40·2	35·0	30·2	15·8	74·1	89·2	89·1	87·6	84·8	79·9
01020*D*	1·6% Mn	63·1	58·6	56·1	54·2	47·0	54·4	85·0	84·9	84·1	82·3	78·4
01020*E*	2·4% Mn	98·6	98·2	93·5	89·4	90·1	45·3	78·5	78·4	76·8	75·2	72·3
01021*F*	0·5% Cr	41·7	37·6	30·3	25·0	5·8	63·0	91·1	90·7	89·6	86·5	80·2
01021*G*	1·1% Cr	48·4	42·1	22·1	16·8	13·7	66·2	88·7	88·4	85·2	81·4	78·5
01021*H*	2·3% Cr	32·0	26·2	15·1	4·3	<1	68·8	84·9	84·4	80·0	75·9	73·1
01021*I*	4·0% Cr	28·8	20·9	4·3	<1	<1	69·5	80·1	79·3	75·2	73·1	70·2
01022*J*	0·5% Ni	30·2	28·6	20·0	5·8	<1	80·1	93·3	92·6	90·1	85·4	82·3
01022*K*	1·0% Ni	33·7	32·1	25·4	11·6	5·1	79·8	92·4	93·1	90·0	85·5	82·7
01022*L*	2·4% Ni	38·8	37·5	34·7	25·5	15·3	76·2	90·9	90·7	90·0	87·7	84·6
01022*M*	4·5% Ni	46·4	45·1	40·0	34·8	26·3	68·7	88·5	88·2	87·4	86·0	83·2

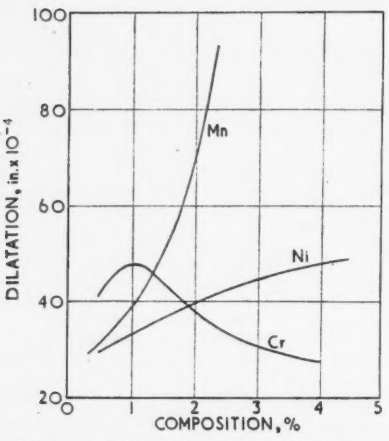

Fig. 3—Effect of alloy content on dilatation due to refrigeration

the phases that may be present in the oil-quenched specimens, only austenite can be irreversibly affected by refrigeration. Therefore, any difference between the magnetic properties of the material in the quenched and refrigerated conditions can only be the result of the production of more magnetic material by the decomposition of austenite. From the magnetic tests it is possible to make an estimate of the percentage transformation taking place, but it was considered advisable, in the preliminary work, to consider relative changes only, and no attempt was made to calibrate the specific magnetism or dilatometer readings to express them in terms of the percentage of austenite transformed. The results are therefore given in terms of dilatation ($\times$ 0·0001 in.) or of percentage specific magnetism, and are related to such standard conditions as were found most suitable to show the trend of the results.

Results

The results obtained are given, in condensed form, in Table II. These results need careful plotting so that allowance can be made for factors such as the change in the inherent magnetic properties of the alloys due simply to changes in composition. Also, one method of plotting will not indicate clearly the effects of both room-temperature ageing and composition, and the results have therefore been plotted in several ways. The derivation of the curves is explained in the text.

To study the effect of the quantity of alloying element on the amount of sub-zero transformation, only the transformation taking place after the minimum period of room-temperature ageing need be considered. In Fig. 3, therefore, the sub-zero dilatation, after a 2-min. time interval, is plotted against the percentage (by weight) of the main alloying element present. The effects of manganese and nickel are similar, differing only in degree, whereas the effect of chromium is radically different. The addition of manganese or nickel increases the amount of transformation taking place during refrigeration, up to the maximum percentage added in this series of experiments. The addition of up to 1% of chromium also increases the sub-zero transformation, but higher-chromium alloys stabilize rapidly during room-temperature ageing and the amount of the transformation decreases.

The magnetic measurements are in good general agreement with the dilatometric results ; to plot them in such a way as to be comparable with those already given is, however, rather difficult. In addition to determining the difference between the specific magnetisms of the material in the quenched and refrigerated conditions, some allowance must be made for the variation in magnetic properties due solely to the change of alloy content. This can be done by expressing the measured specific magnetism figures as percentages of the specific magnetism of the particular alloy in the 'annealed,' *i.e.*, fully ferritic, condition. If the change in specific magnetism due to sub-zero treatment is plotted against the compositions of the alloys, curves comparable with the dilatometric curves given in Fig. 3 are obtained (Fig. 4). The trends of these results are very similar, except that the peak at 1% Cr is not detected ; this is attributed to the lower sensitivity of the magnetic method in this particular case, the actual changes in specific magnetism being relatively small.

To demonstrate the effect of composition on the stabilization of austenite during ageing at room temperature, the amount of sub-zero transformation taking place on refrigeration after the minimum time interval is taken as the reference point, and the results obtained with longer time intervals are expressed as percentages of this figure. The magnetic and dilatometric methods again give very similar curves, but only the dilatometric results have been plotted (Fig. 5), as their sensitivity is greater. The curves show that an increase in either the manganese or the nickel content of the alloys decreases the extent of the room-temperature stabilization, whereas an increase in the chromium content has the reverse effect, the higher-chromium steels stabilizing very rapidly.

Preliminary Conclusions

The tentative conclusions that may be drawn from this preliminary survey (remembering that other factors, such as mass, may have an effect) are as follows :

(1) Increasing the manganese content up to 2·5% rapidly increases the amount of retained austenite after oil-quenching from 900° C., but the majority of

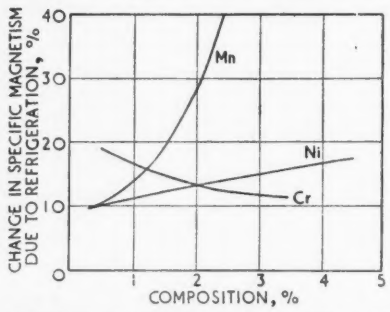

Fig. 4—Effect of alloy content on specific magnetism due to refrigeration

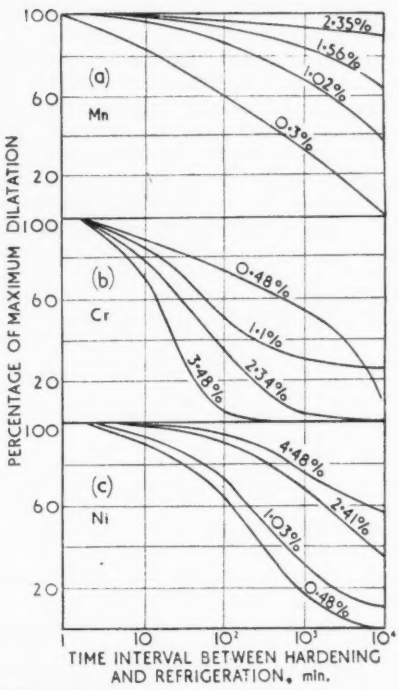

Fig. 5—Dilatation results replotted as percentages of the dilatations obtained on refrigerating 2 min. after the quench, for varying contents of: (*a*) manganese; (*b*) chromium; (*c*) nickel

this austenite is transformed by cooling to — 78° C. The effect of ageing at room temperature decreases as the manganese content increases, up to the maximum manganese content (2·5%) investigated.

(2) The effect of up to 4·5% of nickel is similar to that of manganese, but is less marked.

(3) The effect of chromium is radically different from that of manganese and nickel: chromium steels containing 1–3·5% of Cr are very susceptible to room-temperature ageing, the retained austenite stabilizing very rapidly.

THE EFFECT OF UP TO 10% OF MANGANESE ON A 1% CARBON-BASE STEEL

The results obtained in the preliminary survey were of sufficient interest to require confirmation by a wider range of tests than had hitherto been possible. In this first part of the revised programme, a series of manganese steels containing 1% of carbon and 0·33–10% of manganese was investigated. Ingots weighing 18 lb. were cast from melts made in the high-frequency furnace, and were aluminium-killed; the compositions of the steels are given in Table III. The technique in use was considered sufficiently accurate for the investigation, although it was felt desirable to 'calibrate' the magnetic test method by making spot tests metallographically, and also to obtain better standard specimens of each steel in the fully ferritic condition, from which austenite percentages could be estimated.

The structure resulting from the homogenizing treatment (*i.e.*, 10 min. at 1050° C., followed by cooling in air) contained increasingly large amounts of retained austenite, the 10% Mn alloy being entirely austenitic after this treatment. To break down the austenite, the specimens were soaked at a temperature below A_1 for periods such that after further soaking for at least 24 hr. no further change in the specific magnetism occurred. After preliminary experiments a temperature of 575° C. was chosen, and specimens were packed in cast-iron turnings and soaked for periods of up to 120 hr.; the alloys were examined microscopically and were found to be 100% ferritic. The 'standard' specific magnetisms obtained by this treatment are recorded in Table IV. Assuming that

Table IV

SPECIFIC MAGNETISM AFTER TREATMENT AT 575° C.

Steel	Specific Magnetism, %
01030	93
01029	91
01031	86
01032	85
01082	82
01033	80
01034	80
01083	81
01035	72

the specific magnetism of a fully martensitic structure is the same as that of a ferrite–carbide aggregate in the same steel, these readings represent a 100% martensitic condition, and transformation percentages can be obtained by expressing the measured specific magnetism as a percentage of the relevant standard value. To some extent this assumption is probably incorrect, but it is a necessary compromise. The errors so

Table III

ANALYSES OF 1% CARBON-BASE STEELS CONTAINING UP TO 10% OF MANGANESE

Steel*	C, %	Mn, %	Si, %	Cr, %	Ni, %	W, %	Mo, %	Cu, %	Co, %	Ti, %	Nb, %	Zr, %	Pb, Sn, %	Al, %
01030	0·90	0·33	0·23	0·01	0·02	Nil	0·02	0·02	0·02	0·02	0·03	0·03	0·02	0 27
01029	0·97	1·05	0·31	0·02	0·02	Nil	0·02	0·05	0·03	0·02	0·03	0·03	0·02	0·02
01031	1·02	1·95	0·31	0·02	0·02	Nil	0·02	0·03	0·03	0·02	0·03	0·03	0·02	0·01
01032	0·96	3·10	0·36	0·03	0·02	Nil	0·02	0·02	0·03	0·02	0·03	0·03	0·02	0·05
01082	0·98	4·50	0·32	0·02	0·02	0·02	0·02	0·03	0·03	0·02	0·03	0·03	...	0·32
01033	1·00	5·15	0·38	0·01	0·02	Nil	0·02	0·03	0·02	0·02	0·03	0·03	0·02	0·02
01034	0·96	6·00	0·29	0·01	0·02	Nil	0·02	0·02	0·02	0·02	0·03	0·03	0·02	0·13
01083	0·95	8·30	0·38	0·02	0·02	0·02	0·02	0·03	0·03	0·02	0·03	0·03	...	0·38
01035	0·89	10·0	0·32	0·01	0·02	Nil	0·02	0·02	0·02	0·02	0·03	0·03	0·02	0·03

* The steels contained no vanadium

Table V
PERCENTAGE TRANSFORMATION

Steel	Amount Transformed, %	
	By Microscopic Examination	By Specific Magnetism
01031	69	67
01031	91	91·5
01032	87	85
01082	66	65
01033	57	55
01034	39	38·5
01083	8	6

introduced should be no greater than those involved in making the estimate from microscopic examination, unless, of course, long point-counts or 'lineal analysis'[8] are employed.

To check the above assumption, microscopic examination of a representative set of specimens was carried out by projecting the structures on to the focusing screen of the micrographic apparatus and superimposing a $\frac{1}{10}$-in. net. By counting squares, results consistent to $\pm 1\%$ were obtained by as many as six observers. To allow for the non-uniformity of the structures, a traverse across a diameter (from 6 to 12 fields) was made and the results were averaged. Particular attention was paid to the skin of martensite usually present, so that a true average was obtained. Estimations of percentage transformation, by an independent observer, show that the accuracy was of the order of $\pm 2\%$ (*see* Table V).

Another point to be considered was the austenitizing temperature. If this is wrongly chosen (or rather, if fixed when it should be varied in relation to A_{cm}) false results can accrue; on the other hand, the treatment should be standardized as far as possible if comparative results are to be obtained. The question, therefore, is whether to austenitize all the alloys in a series at a fixed temperature, or to use a temperature a fixed number of degrees above A_{cm}. Bain[15] gives a 1% C section of the ternary Fe–C–Mn equilibrium diagram which shows that the change from ferrite to austenite takes place over a range of temperature but is completed at nearly the same temperature over the whole range of steels investigated. The A_{cm}, however, is rather variable, reaching a maximum at about 4% of manganese. After studying this diagram it was decided to use a temperature which would exceed A_{cm} (maximum) by about 50° C. This temperature, 950° C., would be used for all the alloys; *i.e.*, more attention was paid to the end of the $\alpha \rightarrow \gamma$ change than to A_{cm}. It was also felt desirable to examine the effect of austenitizing temperature on the sub-zero transformation, and a series of tests quenching from 800° C. to 1000° C. at 50° C. intervals was carried out.

RESULTS

The effect of austenitizing temperature was studied on specimens oil-quenched from temperature and then refrigerated after ageing for 10 min. at room temperature; steels 01031, 01032, 01082, 01033, and 01034, *i.e.*, containing 2–6% of Mn, were treated. The results (Fig. 6) show a definite trend with composition, the transformation increasing up to 4% of manganese and then falling off; the trend of the results with temperature, however, is not the same for all the steels. Steels 01031 and 01032 (2% and 3% of Mn) show transformation increasing up to 850° C. and then falling off slightly, transformation in 01082 steel (4·5% of Mn) falls off continuously, and the remaining steels show a fall in transformation with rising austenitizing temperature, up to 850° or 900° C., the amount of transformation again increasing above this temperature. The reason for this change-over is not obvious.

The results of the main series of experiments, on specimens oil-quenched from 950° C. after soaking for 20 min., and then refrigerated at − 78° C. after time intervals of 2–10,000 min., are given in Table VI.

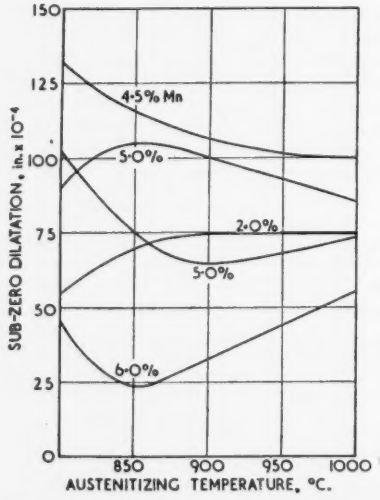

Fig. 6—The effect of austenitizing temperature on subsequent sub-zero transformation

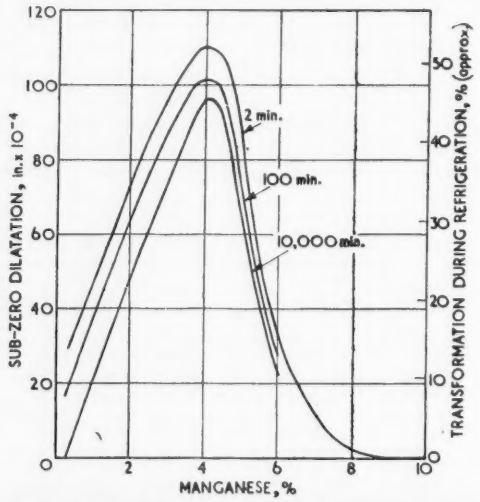

Fig. 7—Dilatation due to sub-zero treatment plotted against manganese content of the alloy

Dilatation Results

The best method of showing the relative order of the sub-zero transformation with respect to composition was found to be to plot the dilatation due to sub-zero transformation against the percentage of manganese in the alloy for a particular treatment. Figure 7 shows curves for time intervals of 2 min., 100 min., and 10,000 min. To make possible a direct comparison of the dilatometric and magnetic results, a further group of specimens was examined under the microscope by the point-counting method, and from these observations an approximate calibration of the dilatometric results was obtained which has been used to provide the percentage transformation scale also given in Fig. 7. The 2-min. curve in this figure is in good agreement with the 'transformation by refrigeration' curve in Fig. 11, which was obtained by the magnetic method. A sharp maximum in the amount of sub-zero transformation is found at about 4% of Mn, and the amount of retained austenite transformed falls off rapidly above this value. This effect is more easily understood from the magnetic measurements, and is discussed later.

The factor most clearly indicated by the dilatometric results is the room-temperature stabilization of the austenite. The trend of the degree of stabilization is seen if the results are expressed as a percentage of the maximum sub-zero dilatation obtained, *i.e.*, the dilatation after a 2-min. time interval (Fig. 8). The percentage dilatation change on ageing decreases markedly up to 4% of Mn and then increases again up to 6% of Mn. At 8% of Mn the percentage dilatation is incommensurate—no dilatation can be measured, and the alloy remains fully austenitic so far as these tests are concerned.

Table VI

DILATATION AND SPECIFIC MAGNETISM RESULTS OF MAIN SERIES OF EXPERIMENTS

Steel	Manganese, %	Dilatation (× 0·0001 in.) at Time After Treatment					Specific Magnetism (%) at Time After Treatment					
		2 min.	10 min.	100 min.	1000 min.	10,000 min.	As Quenched	2 min.	10 min.	100 min.	1000 min.	10,000 min.
01030	0·3	29·3	27·3	15·4	6·5	−0·5	82·4	93·2	91·9	90·0	87·3	82·5
		32·6	21·9	16·9	6·8	−0·7	81·6	92·3	92·4	91·0	88·0	83·0
		25·5	27·1	17·1	6·2	0·3	82·0	92·0	93·4	90·9	87·8	81·0
		27·1	21·3	15·8	7·5	1·2	81·8	94·4	92·6	89·4	87·4	86·4
	Average	28·6	24·4	16·3	6·8	0·1	82·0	93·0	92·6	90·4	87·6	83·3
01029	1·0	48·0	46·0	39·5	34·3	24·0	79·8	89·4	89·5	87·3	86·9	84·1
		45·8	45·4	42·1	28·9	28·5	74·6	89·7	89·3	89·0	86·7	81·0
		42·0	43·4	35·2	30·9	20·5	75·4	90·3	89·7	88·6	87·5	82·4
	Average	45·3	44·9	38·9	31·4	24·2	76·6	89·8	89·5	88·3	87·0	82·5
01031	2·0	75·5	67·6	66·1	59·0	47·1	57·8	80·5	79·7	79·9	79·6	78·8
		75·5	73·5	66·1	55·4	42·1	57·8	81·6	81·2	80·2	80·1	78·7
		75·1	67·3	65·4	61·3	46·2	58·0	81·4	80·2	79·7	79·7	75·9
	Average	75·4	69·5	65·9	58·6	45·1	57·9	81·2	80·4	79·9	79·8	77·8
01032	3·0	102·2	90·2	89·4	78·5	72·2	37·2	75·0	75·0	73·6	73·3	72·0
		95·0	89·1	89·2	86·5	76·0	35·0	75·5	74·2	74·8	71·8	72·3
		102·2	93·0	87·0	83·6	74·8	36·5	77·0	75·5	73·4	75·0	71·9
	Average	99·8	90·8	88·7	82·8	74·3	36·2	75·8	74·9	73·9	73·4	72·1
01082	4·5	108·2	104·0	97·6	102·5	97·1	10·0	54·4	54·6	50·3	51·7	51·0
		106·6	101·5	102·6	96·7	101·0	9·0	52·0	49·9	51·9	51·9	50·0
	Average	107·3	102·7	100·1	99·6	99·0	9·5	53·2	52·3	51·1	51·8	50·5
01033	5·0	75·1	67·8	70·8	66·4	53·6	6·0	34·0	31·8	34·9	34·9	30·8
		80·1	68·7	63·0	59·0	61·8	5·0	37·2	32·0	32·0	31·3	30·0
		71·4	69·9	68·3	62·2	50·5	4·0	32·5	35·2	30·0	31·5	31·6
	Average	75·5	68·5	67·4	62·5	57·5	5·0	34·6	33·0	32·3	32·6	30·8
01034	6·0	40·5	35·6	25·1	24·0	27·8	<1	29·8	26·8	27·5	24·7	24·7
		34·5	47·6	36·2	20·8	25·2	<1	32·0	30·0	29·9	22·5	22·0
		25·5	36·9	27·7	26·4	21·5	<1	27·4	31·5	28·2	26·0	25·2
	Average	33·5	39·3	29·7	23·7	24·8	<1	29·7	29·4	28·5	24·4	24·0
01083	8·0	<1	<1	<1	<1	<1	<1	3·0	3·5	2·0	2·5	2·5
		<1	<1	<1	<1	<1	<1	3·0	2·5	2·0	2·5	2·5
	Average	<1	<1	<1	<1	<1	<1	3·0	3·0	2·0	2·5	2·5
01035	10·0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Average	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

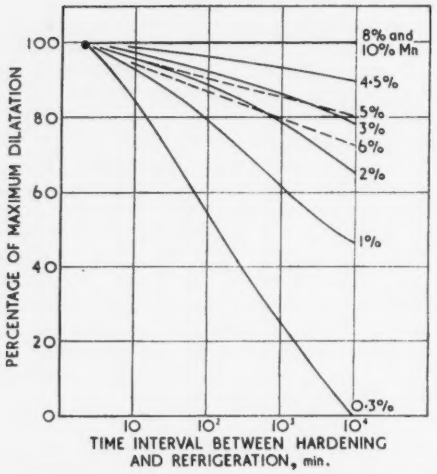

Fig. 8—Percentage of maximum dilatation plotted against time interval between hardening and refrigeration, showing the effect of room temperature ageing

There is some difficulty in the choice of a suitable criterion by which to express the rate of stabilization, and it has been found necessary to choose an arbitrary condition. The condition chosen in this case was the rate, in percentage of maximum dilatation per minute, at a 200-min. interval. The values obtained are plotted against manganese content in Fig. 9.

Magnetic Results

The magnetic method, although not sufficiently sensitive to distinguish satisfactorily the effects of room-temperature stabilization on most of the alloys, enables an estimate to be made of the amount of austenite obtained during the quench, and also the proportion of this austenite breaking down on refrigeration.

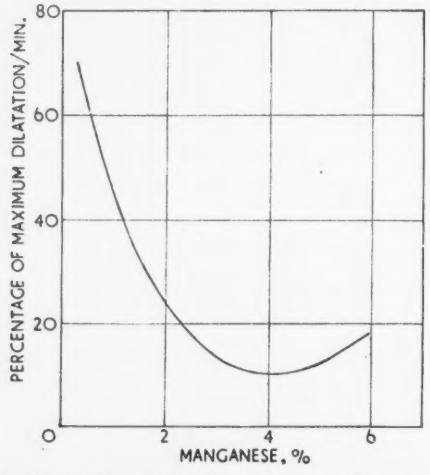

Fig. 9—Rate of stabilization at room temperature, calculated from the slope of the 'percentage maximum dilatation/time interval' curves at 200-min. time interval

The only direct information obtainable from the results in Table VI is that the specific magnetism falls off steadily as the manganese content increases. However, if the specific magnetism after a particular time interval, say 2 min., is plotted against the percentage of manganese in the alloy, the curve shown in Fig. 10 is obtained. The 'standard' specific magnetism (*see* p. 5) of each alloy (Table IV) is also plotted in Fig. 10, together with the average of the 'as-quenched' specific magnetism values for each steel.

The specific magnetism figures indicated by the 'as-quenched' and '2-min.' curves are proportional to the amount of martensite present after the particular treatment for each steel. The values indicated by the 'ferritic' curve can be considered to represent a 100% martensitic condition, with the reservations already discussed, whilst zero specific magnetism indicates 0% of martensite, *i.e.*, 100% of retained austenite.

By expressing the measured specific magnetisms as percentages of the 'ferritic' value for each alloy, they can be considered to represent the percentage of martensite formed during quenching (from the 'as-quenched' curve) and during quenching and refrigeration (from the '2-min.' curve). By subtraction, the amount of martensite formed during the sub-zero treatment for each alloy composition is obtained. These results, in Fig. 11, are also shown in terms of retained austenite. The amount of austenite retained on quenching increases rapidly, until at about 6% of Mn all the austenite is retained. This agrees with Bain's results,[15] which place the boundary between the mixed austenite/martensite structures and complete austenite retention, on oil-quenching, at 6% of Mn in 1% C alloys. Up to 4% of Mn, the amount of retained austenite transformed on cooling to — 78° C. increases, but not as rapidly as the amount of retained austenite due to the quench. Consequently, the amount of austenite remaining after refrigeration increases steadily. Above 4% of Mn, the sub-zero transformation during cooling

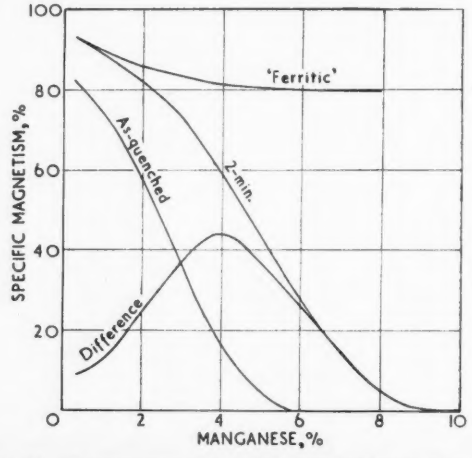

Fig. 10—Comparison of specific magnetisms of manganese alloys after various treatments

decreases in extent, and at about 9% of Mn no martensite is formed, *i.e.*, all the austenite is retained, sub-zero cooling having no effect.

There were two reasons why a lower limit of — 78° C. was imposed in these experiments. The first is that, for practical purposes, the temperature — 78° C. (which can be reached easily by using solid carbon dioxide and one of several organic liquids) is the lowest that can be obtained economically. Lower temperatures entail the use of liquid gases (air, oxygen, hydrogen, etc.), and would be far too expensive in all but the most exceptional cases. Secondly, once the effect of cooling to — 78° C. is known the result of cooling to lower temperatures can be estimated, since the general trend of sub-zero transformation has been firmly established by Cohen.[3–13] In the present case, further cooling would be expected to increase to some extent the amount of transformation. Since, however, it is known[16] that cooling a 12–13% Mn steel to the lowest attainable temperatures does not cause any transformation, the shape of the curves would be little altered. The peak obtained at about 4% of Mn agrees well with other properties, *e.g.*, forgeability, of manganese steels, and may be fundamental.

CONCLUSIONS

At this stage the results obtained may be summarized as follows :

(1) The amount of austenite retained on quenching from 950° C. into oil increases rapidly up to 6% of manganese, above which all the austenite is retained.

(2) Refrigeration breaks down part of this austenite, the proportion decreasing with increasing manganese ; no transformation takes place in alloys containing more than 9% of manganese.

(3) The amount of transformation rises to a maximum with about 4% of manganese and then falls off rapidly. This is due to the control of the sub-zero transformation by two factors :

(i) The amount of austenite produced by the quench

(ii) The stabilization of the austenite by (*a*) alloy content, which causes the increase in the amount of austenite retained in quenching but the decrease in the amount of sub-zero breakdown, and (*b*) ageing at room temperature, which generally decreases with increasing manganese content and, for most of the alloys, is not of major importance.

The factor (i) has the major effect with the low-alloy contents, but is outweighed by (ii) when the manganese content exceeds 4%.

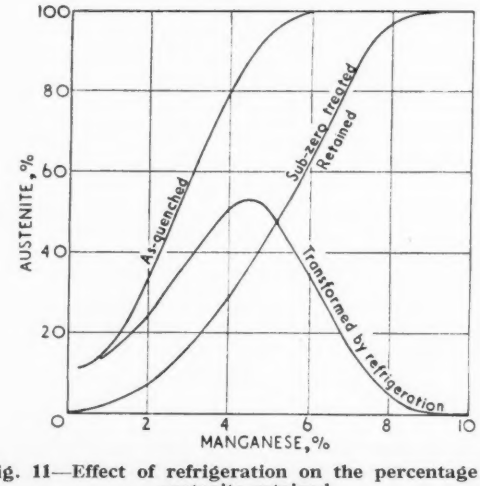

Fig. 11—Effect of refrigeration on the percentage of austenite retained

Acknowledgments

The authors wish to thank various colleagues in the Research Department, particularly Mr. T. H. Arnold, for advice in the early stages, and Mr. E. H. Booth, for the metallographic work.

Acknowledgment is also due to Mr. E. W. Colbeck, Metallurgical Director, for permission to publish this paper.

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APPENDIX

The Use of Organic Liquids to Obtain Steady Sub-Zero Temperatures by the Addition of Solid Carbon Dioxide

In practice, solid CO_2 is seldom surrounded by an atmosphere of pure CO_2 vapour ; hence its temperature is considerably lower than the normal sublimation temperature, — 78·5° C. The 'solid' temperature is that at which the solid CO_2 has a vapour pressure equal to the partial pressure of the CO_2 vapour in the atmosphere immediately surrounding the solid.

The accepted method of taking a CO_2 point is to place crushed CO_2 in a thermos flask and to insert

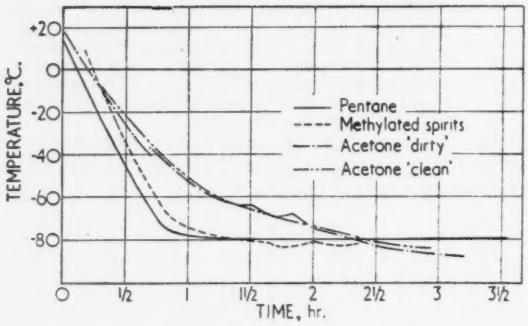

Fig. 12—Cooling curves for acetone, methylated spirits, and pentane, mixed with solid carbon dioxide

an electrical heating coil in the CO_2 near the bottom, about 1 in. below the couple or thermometer under test. With this method, the initial temperature measured is lower than the sublimation point; but, with the heater dissipating about 10 watts, the evaporating CO_2 expels the air and the temperature rises to a steady $-78{\cdot}5°$ C., remaining there for a considerable time.

Mixtures of liquids and crushed solid CO_2 do not behave very differently from solid CO_2 alone, exhibiting an initial low temperature and then a general rise. Acetone, methylated spirits, and pentane have been tested, and their behaviour is shown in the cooling curves, Fig. 12.

The first liquid used was acetone which had been used many times previously in refrigeration work (termed 'dirty' acetone). Additions of 40 g. of solid CO_2 were made every 10 min., and steady cooling was obtained down to $-40°$ C. when there was a sharp rise in temperature, the liquid becoming 'cloudy.' The consistency of the liquid became creamy in the region of $-60/-70°$ C., and further irregularities in the curve were found.

New 'clean' acetone was tried next and was found to remain colourless throughout, but the minimum temperature of $-86{\cdot}35°$ C. was almost the same as the $-86{\cdot}3°$ C. measured with the 'dirty' acetone. In both cases there was a great excess of CO_2, and the mixture was violently stirred before readings were taken.

Methylated spirits took much longer to cool down, and the rate of CO_2 addition was increased to 60 g. every 8 min. A minimum reading of $-81{\cdot}75°$ C. was obtained, and the addition of larger amounts of CO_2 was found to cause fairly large falls in the temperature, which subsequently slowly recovered.

With standard pentane a very rapid rate of cooling was obtained, and a temperature of $-79{\cdot}1°$ C. was held for more than 2 hr. in spite of further additions of CO_2. The lowest temperature obtained was $-80{\cdot}6°$ C. after adding a great excess of CO_2, but the temperature rose reasonably quickly to the previous figure of $-79{\cdot}1°$ C.

Other experiments involving the artificial 'dirtying' of methylated spirits and pentane with oil, water, etc., emphasized the superiority of standard pentane, which appears to be the best medium for use in laboratory refrigeration work.

Phosphate Coatings as a Basis for Painting Steel

By the Phosphate Coatings (Drafting) Panel of the British Standards Institution

SYNOPSIS

An account is given of the results obtained when analytical and performance tests were applied to industrial phosphate coatings. The addition of small amounts (about 0·1%) of chromic acid to the water used for rinsing after phosphating was found to improve the protective properties of the coating, but high concentrations (>approx. 0·5%), were injurious because the coating was dissolved.

THE British Standards Institution has considered for some time the possibility of drafting standards for phosphate coatings, with particular reference to their use as a basis for painting steel. Although no standard has yet been issued, some research has been carried out; the results so far obtained and the interim conclusions drawn are given in this paper.

The work has been conducted by members of B.S.I. Panel CHE/18/4/1, the constitution of which was as follows:

Dr. J. C. Hudson (*Chairman*)	British Iron and Steel Research Association
Mr. G. Murray	Pressed Steel Co., Ltd.
Mr. R. St. J. Preston	Chemical Research Laboratory
Mr. R. H. Settle	Government Laboratory
Mr. W. H. Tonkinson	Pressed Steel Co., Ltd.
Dr. W. H. J. Vernon, O.B.E.	Chemical Research Laboratory
Mr. H. T. Lawrence (*Secretary*)	British Standards Institution
Mr. E. I. Brimelow	Ministry of Works
Dr. S. G. Clarke	Armament Research Establishment

The Panel was set up in August, 1944 and its activities continued until July, 1948. These included

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the drafting of B.S.I. Publication PD.539 : 1946, and the conduct of the work which is described in this report. The suitability of various analytical and performance tests for standardization purposes, and the effects of chromic acid rinses on the protective properties of phosphate coatings are discussed.

TESTS FOR PHOSPHATE COATINGS

Analytical Tests

The analytical tests suggested for phosphate coatings have been described fully elsewhere.[1] They include determinations of the following properties of the coating :

(i) Weight per unit area —obtained by stripping the coating in inhibited acid

(ii) Phosphate content—found by dissolving the coating in hydrochloric acid, and determining the phosphate content of the solution by a colorimetric method, based on the formation of a phospho-molybdate-hydroquinone complex

(iii) Moisture content—determined by drying for 1 hr. at 105° C.

(iv) Hygroscopicity—determined by observing the increase in weight of samples after suspension over water for 1 hr. under standard conditions

(v) Absorption value—determined from the increase in weight of the coating, when immersed in diacetone alcohol under standard conditions.

Performance Tests

The performance tests used in the investigations included two laboratory corrosion tests, namely the A.R.E. test and the C.R.L. test, and several outdoor corrosion tests.

The A.R.E. test[2] consists of spraying the specimens once a day with sea water, so as to cover them with a layer of discrete droplets. Evaporation of the droplets between sprayings is minimized by storing the specimens over water in an enclosed space.

The C.R.L. test has been described by Preston.[3] The apparatus consists of a 5-litre beaker fitted with a cover, an electric heater, a water-cooling device, and a thermostat. The specimens are suspended inside the beaker over 500 ml. of dilute SO_2 solution. When the heater is turned on and cold water is run through the cooling coil, condensation is promoted on the surface of the specimens. The thermostat cuts off the heating coil when the temperature of the vapour reaches 45° C.

The outdoor tests need no description.

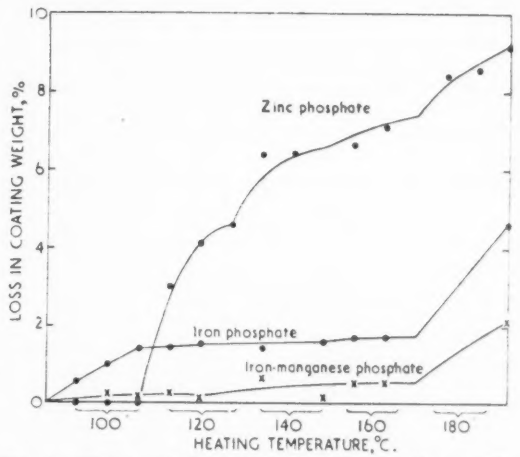

Fig. 1.—Effect of heating on phosphate coatings [The points given for each temperature correspond successively to heating times of 1, 2, and approx. 16 hr.]

Application to Industrial Phosphate Coatings

The analytical tests were first applied to six different types of industrial phosphate coatings, the specimens being prepared under production conditions. Details of the processes were recorded. Some of the tests, particularly the determination of the moisture content, may be affected by the conditions of drying and storage between phosphating and analysis. To minimize this effect, the specimens were packed in bags of impermeable material immediately after they had been dried by the method normally used at the plant concerned.

The results of the analytical tests are given in Table I. The properties of these industrial phosphate coatings, all of which are satisfactory in use, vary widely, and so it would be difficult to draft a rigorous analytical specification that could be applied fairly

Table I

ANALYTICAL TESTS ON INDUSTRIAL PHOSPHATE COATINGS

Process	*P*	*S*	*T*	*Q*	*V*	*R*
Main Cation in Phosphate Bath	Fe	Mn	Zn	Zn	Zn	Zn
Method of Application	Immersion	Immersion	Spraying	Immersion	Immersion	Immersion
Duration of Treatment, min.	15	30	1·5	4	5	12
Change in weight. on phosphating, g./sq. ft.	−2·40	−2·43	0·24	0·31	0·15	0·54
Coating weight., g./sq. ft.	1·31	1·95	0·41	0·50	0·32	1·13
PO_4, g./sq. ft.	0·64	0·82	0·18	0·19	0·11	0·41
Moisture, mg./sq. ft.	7·5	7	14	34	16	71
PO_4 content of coating, %	49	42	44	38	34	36
Moisture content of coating, %	0·6	0·4	3·4	6·9	5·0	6·4
Hygroscopicity of coating, %	0·3	0·2	1·2	1·3	1·0	1·5
Absorption value, g./sq. ft.	1·05	1·0	1·0	1·2	1·0	1·1

Table II

VARIATION IN WEIGHT OF PHOSPHATE COATING IN ROUTINE PRODUCTION*

Batch No.	Coating Weight, g./sq. ft.		
	I	II	Mean
1	0·785	0·806	0·795
2	0·875	0·936	0·906
3	0·849	0·779	0·814
4	0·922	0·922	0·922
5	0·864	0·922	0·893
6	0·887	0·839	0·863
7	0·849	0·839	0·844
8	0·590	0·612	0·601
9	0·806	0·887	0·847
10	0·670	0·684	0·677

* The average interval between batches was 2–3 days

to all the processes. For example, the weight of the phosphate coating varies from 0·23 to 1·95 g./sq. ft., *i.e.*, in the ratio 1 : 6. There is less variation in the phosphate (PO_4) content, which lies between 34% and 49% ,and it might be possible to use this characteristic for specification purposes. More information would first be required, however, on the behaviour of coatings falling outside this range of phosphate content.

Results indicate that the moisture content and the hygroscopicity are greater for coatings based on zinc phosphate than for coatings based on iron or manganese phosphate : the average moisture content of the coatings produced by processes *Q*, *R*, *T*, and *V*, in which zinc phosphate is used, is 5·4%, as compared with 0·6% for process *P* (iron phosphate) and 0·4% for process *S* (manganese phosphate). This observation is supported by the results of a test made at the Chemical Research Laboratory, in which three different phosphate coatings were heated at successively increasing temperatures from 100 to 180° C. The percentage losses in weight of the coatings are shown in Fig. 1 ; the zinc phosphate coating lost much more weight than the iron phosphate and iron–manganese phosphate coatings. The zinc phosphate coating contained an appreciable amount of combined water, which was driven off by heating, and the curve indicates that three molecules of water of crystallization may have been present. A relatively high moisture content may be characteristic of zinc phosphate coatings, but further work is needed to substantiate this.

In contrast to other results obtained by Preston,[3] no correlation was observed between weight of phosphate coating and loss in weight caused by corrosion when bare phosphate-coated specimens, without any organic finish, were exposed to a C.R.L. test. The conditions of test differed considerably, however, from those that have since been standardized ; in particular the strength of the sulphur dioxide solution was stronger, and the test duration was only 24 hr.

Application to Routine Production

Arrangements to try out the tests on a much wider range of phosphate coatings have now been made with the help of industrial users, who have undertaken to test routine production samples in their laboratories and to report the results.

In pilot tests made at a single works, as a preliminary to this major investigation, ten sets, each of ten 6 in. × 4 in. × 20 S.W.G. blank steel panels, were phosphated at intervals of two or three days in a bath in current use. The first nine sets of specimens were passed through the drying oven after phosphating, and were then stored for periods up to three weeks until the tenth set was prepared. All the sets were then passed through the drying oven simultaneously.

Two specimens from each batch were used for the determination of coating weight and six of the remainder for corrosion tests. The latter were tested in the painted condition, the paint used being a single coat of stoving paint to specification CS.2249, applied by dipping, and stoved at 350° F. The paint film was damaged before test by scratching and indentation, as provided in PBS.1391 : 1947.

The results of the coating weight determinations are given in Table II. The average coating weight varies from 0·601 to 0·922 g./sq. ft., *i.e.*, by rather more than 50%. The reproducibility between duplicates is reasonably good, and some of the differences observed between them were probably genuine.

An A.R.E. test over 6 weeks, and an outdoor exposure test at an angle of 45° over 33 weeks, were carried out, each in triplicate. Taking general rusting as the criterion of failure, at the end of the laboratory test, 37% of the surfaces had failed, 38% were about to fail, and the remaining 25% were intact. At the end of the field test, 55% of the surfaces had failed, the failure of 23% was imminent, and 22% had not failed. The average losses in weight of bare-steel control specimens were 11·1 g. and 8·2 g. in the A.R.E. test and in the field test, respectively ; the latter value corresponds to a corrosion rate of 2·1 mils/year. There was no correlation between the weight of the phosphate coating and the performance of the protective scheme in either test, the values of the correlation coefficients between order of merit of coating performance and weight of coating being −0·35 for the A.R.E. test and 0·03 for the outdoor test. It was concluded, therefore, that in the preliminary experiments variations in weight of phosphate coating of up to 50% had no obvious effect on coating efficiency.

Table III

EFFECT OF CHROMIC ACID RINSES ON PHOSPHATED AND PAINTED SPECIMENS

(Outdoor Exposure)

Chromic Acid (CrO_3) in Rinsing Water, %	Duration of Test to Failure, yr.	
	Phosphating Process *A*	Phosphating Process *B*
Nil	0·3	0·5
0·05	0·5	0·5
0·1	0·6	1·0
0·2	0·6	1·0
0·5	0·6	0·8
1	0·6	0·5
2	0·6	0·1
5	0·2	0·0

Table IV

EFFECT OF CHROMIC ACID RINSES ON BARE PHOSPHATED SPECIMENS (A.R.E. Test)

Chromic Acid (CrO_3) in Rinsing Water, %	Wt. of Steel Corroded, mg. per specimen	
	Phosphating Process *A*	Phosphating Process *B*
Nil	572	83
0·05	613	22
0·1	467	47
0·2	198	94
0·5	198	126
1	15	157
2	40	122
5	226	276

EFFECTS OF RINSING ON PHOSPHATE COATINGS

In several phosphating processes, the phosphated article is given a hot-water rinse between its withdrawal from the phosphating bath and its transfer to the drying oven. Often chromic acid or a soluble chromate is added to the rinsing water.

The B.S.I. Panel studied the effect of chromic acid additions to the rinsing water by testing eight sets each of several specimens which were phosphated by either of two processes followed by a chromic acid rinse. The specimens were cut from 20-gauge autobody sheet and were 6 in. long by 3 or 4 in. wide, according to the test to be made on them. For each process, the same procedure was followed throughout, except that the concentration of chromic acid in the rinsing solution was varied for each set of specimens as follows : Nil, 0·05%, 0·1%, 0·2%, 0·5%, 1%, 2%, and 5%.

In the first process *A*, the specimens were immersed in the bath for six min. at 140° F., and in the second *B*, for 10 min. at 180° F. After phosphating, both sets of specimens were dipped in water at 150–160° F., and were rinsed in chromic acid solution at 160° F. All the specimens were dried in an oven at 270–290° F. for 6 min. The main cation in both phosphating solutions was zinc.

Analytical tests of the coatings were made (*see* p. 11), and sets of specimens were subjected to laboratory corrosion tests and to outdoor exposure. Some of the corrosion tests were made on specimens to which a single coat of stoving paint CS.2249 had been applied. The average weight of the dry paint film was 0·019 g./sq. in., which is approximately equivalent to a thickness of 0·5 mil. The paint was damaged before exposure as provided in PBS. 1391 : 1947.

Outdoor-Exposure Tests

Sets of specimens were exposed outdoors at Birmingham at an angle of 45°, facing approximately south, with the damaged surface uppermost, from October, 1946 to June, 1948. Test duration to failure in terms of PBS.1391 : 1947 was determined for each specimen by means of inspections at monthly intervals. The results for the upper surfaces, given in Table III, show that for both phosphating processes, the performance of the protective scheme improved with increasing additions of chromic acid to the rinsing water, up to a limiting concentration. Beyond this point performance deteriorated, and the strongest rinses used (2 or 5% of CrO_3) proved harmful.

After the point of failure had been passed, further breakdown was not greatly affected by whether or not a dilute chromic acid rinse had been used, and when the test was concluded after 1·7 years' exposure, there was little difference in appearance between the specimens treated with the more dilute rinses and those rinsed in pure water. Those treated with the strongest rinses were, however, inferior throughout.

The A.R.E. Test

The results of a 7-day A.R.E. test on the bare phosphate coatings are given in Table IV : in both processes, the addition of chromic acid to the rinsing water up to a certain limiting concentration improved the corrosion resistance of the coating, but greater concentrations proved injurious. Coating *B* was more resistant than coating *A*, possibly because the coating weight of the former was about four times greater.

Similar 7-day tests on a set of painted specimens

Table V

ORDER OF MERIT OF THE SPECIMENS

Chromic Acid (CrO_3) in Rinsing Water, %	Order of Merit									
	Phosphating Process *A*					Phosphating Process *B*				
	Outdoor Exposure	A.R.E. Test		Total	Overall Order	Outdoor Exposure	A.R.E. Test		Total	Overall Order
		Bare	Painted				Bare	Painted		
Nil	7	7	7	21	7½	5	3	6	14	5
0·05	6	8	4	18	6	5	1	3½	9½	3
0·1	3	6	1½	10½	4	1½	2	5	8½	2
0·2	3	3½	1½	8	1	1½	4	1	6½	1
0·5	3	3½	3	9½	3	3	6	2	11	4
1	3	1	5	9	2	5	7	3½	15½	6
2	3	2	6	11	5	7	5	8	20	7
5	8	5	8	21	7½	8	8	7	23	8

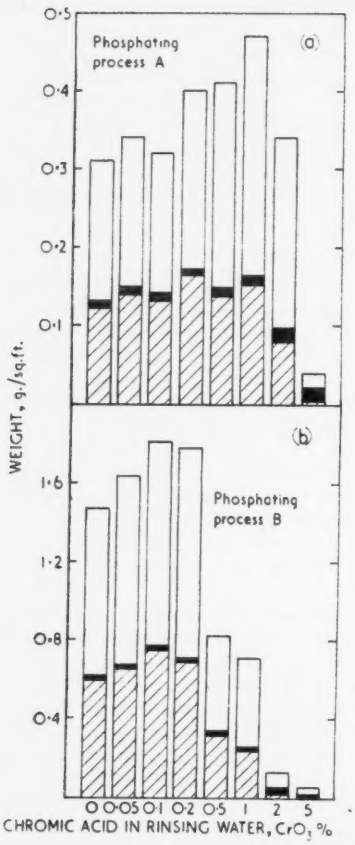

Fig. 2—Effect of chromic acid rinses on the weight and composition of phosphate coatings [Whole bar denotes coating weight, shaded area denotes phosphate content (as PO_4), middle area denotes moisture content (as H_2O)]

gave the final order of merit shown in Table V. Although this order does not agree exactly with the order of merit for bare phosphate coatings it reveals the same general effect of the addition of chromic acid to the rinsing water.

Discussion of Results

The figures given in Table V suggest that the optimum concentration of chromic acid is 0·1–0·2% CrO_3.*

With painted specimens, good correlation was observed between the orders of merit in the A.R.E. test and in the outdoor test, the correlation coefficients being 0·82 for process *A* and 0·83 for process *B*. This confirms the value of the performance test specified in PBS.1391 : 1947 for protective schemes of this type.

The results of the analytical tests of the coatings, which are given in Table VI, show that for both phosphating processes, the coating weight increases to a maximum with increasing chromic acid content of the rinsing water, and then decreases rapidly, almost to zero (*see* Fig. 2), indicating that at high concentrations the chromic acid rinse dissolves the phosphate coating.

As the concentration of chromic acid in the rinsing water increases, there is an increase in the chromic oxide content of the coating, expressed as a percentage of the total coating weight. There is slight evidence of an unexplained increase in the percentage of phosphate present in the coating, more especially with process *A* but the small increase observed may be within experimental error.

The moisture content and hygroscopicity figures both show some improvement with about 0·2% or less of chromic acid in the rinsing water. The absorption value is not greatly affected at first, but falls off for the highest concentrations of chromic acid, presumably because of a corresponding reduction in the coating weight.

The results also show that the coating weight is about four times greater for the phosphate coatings produced by process *B* than it is for coatings produced by process *A*.

The circumspect use of chromic acid rinses has a beneficial effect in the case of the two phosphating processes tested. This is not necessarily so for all processes. The necessity for rinsing after phosphating probably varies with the particular process used, and is much greater for processes containing certain substances added to accelerate the formation of the phosphate films than it is for long-period immersion processes, using ordinary iron phosphate baths.[4] It seems certain that a water rinse can never do any harm, and it is a wise precaution to rinse articles which have folds and crevices that may entrap phosphating solution.

CONCLUSIONS

(1) In spite of the wide range of industrial phosphating processes, it might be possible, on the basis of the tests described in the paper, to draw up specifications for individual processes, if each specification were strictly limited to the particular process concerned, and if the criteria of acceptance were suitably related to the purpose for which the phosphate coating was required. Such specifications might be based on a performance test for a specimen phosphated by the process concerned, and provided with a standard organic finish of oil, lacquer, or paint, which would be required to show a specified performance in a standard laboratory corrosion test. Experimental work to explore this possibility is in progress.

(2) In tests on two industrial phosphate coatings, the addition of small concentrations of chromic acid to the rinsing water used after phosphating had a beneficial effect on the protective properties of the coatings, but a high concentration dissolved the coatings. The permissible limiting concentration of chromic acid probably varies for different phosphating processes, but even very dilute solutions with concentrations as low as 0·05% may have a beneficial effect.

Acknowledgments

The investigations reported in this paper were made on a collaborative basis by the individual members of B.S.I. Panel CHE/18/4/1 and were greatly

* Amendment No. 1 to PD.539 : 1946 gives the upper limit as 0·5%.

Table VI

ANALYTICAL TESTS ON PHOSPHATE COATINGS RINSED WITH CHROMIC ACID

Chromic Acid (CrO_3) in Rinsing Water, %	Nil	0·05	0·1	0·2	0·5	1	2	5
				Phosphate Process *A*				
Coating weight,* g./sq. ft.	0·31	0·34	0·32	0·40	0·41	0·47	0·34	0·04
Coating weight,† g./sq. ft.	0·32	0·40	0·47	0·44	0·55	0·50	0·39	0·21
PO_4, g./sq. ft.	0·123	0·140	0·132	0·164	0·138	0·153	0·080	0·005
CrO_3, mg./sq. ft.	Nil	0·90	1·06	3·98	8·1	16·7	25·4	4·78
Moisture, mg./sq. ft.	8·1	7·8	7·7	7·6	9·0	11·3	17·7	15·8
PO_4 content of coating, %	39·9	41·3	41·2	41·1	33·8	32·5	23·4	12·6
CrO_3 content of coating, %	Nil	0·29	0·28	0·83	2·01	3·6	9·5	12·0
Moisture content of coating, %	2·6	2·3	2·4	1·9	2·2	2·4	5·2	39·6
Hygroscopicity of coating, %	1·6	0·7	0·9	0·8	0·9	1·0	1·4	11·9
Absorption value, g./sq. ft.	0·94	0·98	0·94	0·93	0·96	0·98	0·91	0·85
				Phosphate Process *B*				
Coating weight,* g./sq. ft.	1·47	1·64	1·81	1·78	0·82	0·71	0·13	0·05
Coating weight,† g./sq. ft.	1·52	1·80	1·89	1·69	0·90	0·49	0·42	0·18
PO_4, g./sq. ft.	0·598	0·655	0·750	0·688	0·321	0·242	0·0164	0·0009
CrO_3, mg./sq. ft.	Nil	Trace	2·23	2·72	5·36	19·2	25·6	19·3
Moisture, mg./sq. ft.	19·1	21·3	19·9	17·8	13·1	16·3	25·2	20·9
PO_4 content of coating, %	40·6	39·9	41·4	38·6	39·4	34·1	12·6	1·7
CrO_3 content of coating, %	Nil	Trace	0·12	0·16	0·59	2·6	9·5	32·1
Moisture content of coating, %	1·3	1·3	1·1	1·0	1·6	2·3	19·4	41·7
Hygroscopicity of coating, %	0·4	0·3	0·3	0·2	0·5	0·4	5·8	13·0
Absorption value, g./sq. ft.	1·08	1·13	1·21	1·18	0·98	0·93	0·88	0·83

* Duplicate determinations using sulphuric acid inhibited with di-o-tolyl thiorea
† Duplicate determinations using Clarke's solution

facilitated by official support received from the Chemical Research Laboratory and the Government Laboratory, in the latter case by arrangement through the Ministry of Works.

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Corrosion by Retained Treatment Chemicals on Phosphated Steel Surfaces

By S. G. Clarke, D.Sc., and E. E. Longhurst, Ph.D.

SYNOPSIS

Results are presented of humid-atmosphere corrosion tests, which show that small amounts of the treatment solution that may be retained on the surface after phosphating steel by plain phosphoric acid–metal phosphate phosphating processes are relatively innocuous. This is not always so when the phosphating solution contains accelerating agents; efficient washing-off may then be required. A simple performance test is suggested as a guide if the corrosive tendency of a phosphating solution is not known or if the geometry of the parts treated makes effective washing difficult.

An investigation was carried out using sheet-steel specimens having a dent in the flat surface to receive drops of the phosphating solution, for direct observation of any corrosive effect, and having overlaps under which the solution might be entrapped. Three different phosphating processes, claimed to be quite satisfactory without rinsing off residues of the treatment solution after the coating has been formed, and for comparison, one process requiring after-rinsing, were tested. These processes were representa-

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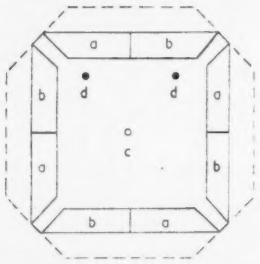
tive of ' hot-bath ' processes working at a moderate acidity ; ' panel washes,' which are often more strongly acid solutions, were not included.

PREPARATION OF SPECIMENS

Form of Specimens

Figure 1 shows the design of the specimen prepared from 20-gauge, bright cold-rolled, deep-drawing mild-steel sheet. After drilling the suspension holes and making a dent in the centre of the specimen by a standard blow of 18 in.lb. from a ball-ended hammer, the edges were folded over, giving a 4-in. square with a ½-in. overlap along each edge. The fold-over was flattened in a vice along half the length of each side of the specimen, producing a tight fold with a very narrow crevice, and leaving the other half of each side with a more capacious crevice. This was done to give a sequence of tight and open folds alternately all round the specimen, so that by processing the specimen (phosphating, washing, drying, and subsequent dip-painting), in a vertical position, each kind of fold would be in a representative position in respect to drainage effects.



a flat crevice *c* indentation
b open crevice *d* suspension holes

Fig. 1—Diagrammatic face view of specimen

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One set of specimens was prepared from steel sheet which had been thoroughly degreased in trichlorethylene, and another set was prepared from the steel after it had been lightly oiled with a mineral oil of medium viscosity, applied by a cloth, to allow for the oiliness of the steel surface in the folds, which might affect the completeness of phosphating or retention of liquid.

All specimens were vapour degreased in trichlorethylene for 2–3 min. before phosphating, to remove accessible oil. With oiled steel this still left a small amount of oil in the folds, as is usual in fabricated steel work.

Surface Treatment of Specimens

Thirty-two specimens, comprising eight sets of four specimens were treated. Each individual in a set of four was treated by a different phosphating process.

Set 1—' Dry ' crevices, washed, bare phosphating
,, 2—' Dry ' crevices, not washed, bare phosphating
,, 3—' Oily ' crevices, washed, bare phosphating
,, 4—' Oily ' crevices, not washed, bare phosphating
,, 5—As 1, painted
,, 6—As 2, ,,
,, 7—As 3, ,,
,, 8—As 4, ,,

Phosphating—The four commercial processes used were applied under the normal conditions appropriate to the processes ; iron process tanks were used, and the specimens were suspended vertically in the baths.

Process I (iron phosphate) applied in the proprietor's works, under supervision. Phosphating time 40 min. ; pointage 30.*

Process II (iron phosphate, non-proprietary) applied in laboratory. Phosphating time 60 min. ; pointage 20.

Process III (manganese phosphate) applied in laboratory. Process time 60 min. ; pointage 30.

Process IV (zinc phosphate with nitrate accelerator) applied in laboratory. Process time 30 min. ; pointage 20.

With the exception of process IV, the solutions contained only the metal phosphate in dilute phosphoric acid. Processes I and IV were similar, respectively, to processes *P* and *V* that were studied by a committee of the British Standards Institution,[1] but, since there were differences in conditions, *e.g.*, in processing time, the coatings were not strictly comparable.

The phosphated surfaces were normal in appearance except for surfaces treated by process I, where the coating appeared rather thin and uneven (the suppliers, however, were of the opinion that the specimens were satisfactory for the test). All specimens made from oiled sheet showed occasional small patches near crevices from which a slight exudation of oil occurred in treatment ; this appeared to have prevented complete phosphating.

Washed Specimens—The washing after phosphating consisted of immersion in cold tap water for 2 min. ; immersion in hot water (80° C.) for 2 min. ; immersion in hot solution (80° C.) of chromic acid (0·05%) for 2 min. The specimens were then dried for 15 min. in a vertical position in an oven at 120° C.

Not-Washed Specimens—After withdrawal from the phosphating bath, the specimens were allowed to drain for a short time, in a vertical position, becoming apparently dry. They were then laid face upwards and approx. 0·5 ml. of the bath solution was placed in the indentation. The specimens were dried horizontally for 15 min. in an oven at 120° C.

Painted Specimens—Paint was applied by dipping in an off-white stoving paint of a consistency that gives a dried film weight of 1 oz./sq. yd. (approx. 0·5 mil). The paint was based on an oil-modified alkyd resin and conformed to specification CS.2249. The specimens were drained (drainage excess being removed from the lower edge), air-dried in a vertical position, and were finally stoved for 20 min. at 177° C.

CORROSION TEST

The test was one of storage in a damp atmosphere. The specimens were laid flat, face upwards, on supporting glass rods, over a layer of water in shallow metal trays and were covered by loosely fitting sheet-metal covers. The trays were kept on a bench at room temperature, which varied between 15 and 27° C. The total time of test was eight weeks.

* The pointage equals the number of ml. of 0·1 *N* sodium hydroxide required to neutralize 10 ml. of the processing solution to phenolphthalein indicator.

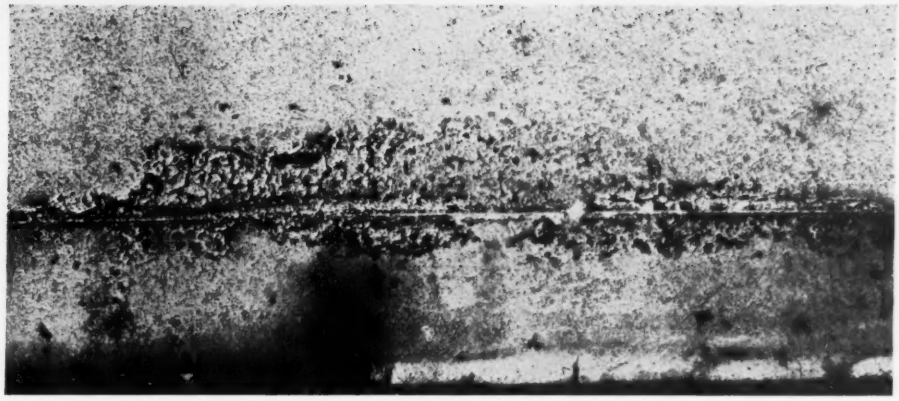

Fig. 2—Cracking and lifting of paint near bottom crevice; phosphating process 1, specimen not washed after treatment × 2

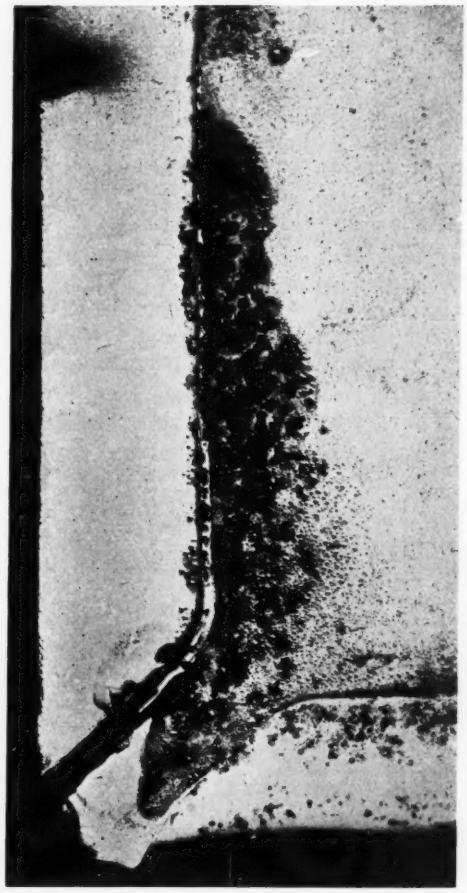

Fig. 3—Rust and blisters near side crevice: phosphating process IV, specimen washed after treatment × 2

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Visual Examination of Specimens

Within the first two days it was noticed that some moisture had condensed both on the bare and on the painted unwashed specimens treated by process IV, and rusting of these had commenced; specimens treated by the other processes remained unaffected at this stage. The appearance of the non-oily steel sheet after two months is summarized in Table I. Specimens made from oily steel sheet showed a tendency for oil to exude from crevices during phosphating (despite degreasing before phosphating). This occasionally produced an area of apparently untreated steel near a crevice where there was a tendency to local rusting in the corrosion test.

The specimens were then removed from the humid atmosphere, and were exposed to the air of a room for a further two months, and were then re-examined. The paint had now spontaneously cracked and lifted near the lower crevice and around the dent on 'not-washed' painted specimens treated by process I (*see* Fig. 2). A slight roughening of the areas affected had been observed throughout the test, and this was associated with a type of incrustation formed from the dried-on processing solution. The fact that other processes did not cause this effect was attributed to the residues remaining less concentrated locally. The freer degree of spreading had probably been promoted by these other phosphate coatings because of a thicker or more even film.

Subsequently, surfaces inside crevices were exposed for examination by filing away the edge of the specimen and lifting off the steel overlap. Penetration of treatment solution and of paint had occurred to varying degrees; generally the penetration was deep in the open-type crevices but only slight in the tight crevices. Rusting within crevices was variable but generally appeared to be less than that around the mouths.

DISCUSSION OF RESULTS

The usual washing treatment after phosphating by accelerated processes is rinsing in a bath of running cold water followed by dipping in hot water containing a chromate or chromic acid, but it is claimed[2] that the chromic rinse is not always effective in preventing corrosion caused by seepage on parts containing crevices, and that it is advantageous to replace the hot-water dip by immersion in a dilute zinc phosphate–phosphoric acid solution operated at a pointage of 10 at 70–100° C. for 2–5 min. In a German patent,[3] fabricated steel parts with overlapping joints or riveted construction, which have been phosphated in baths containing nitrate or nitrite, are subjected to further treatment by immersion for 1–10 min. at 90° C. in a plain phosphoric acid–metal phosphate (manganese or zinc) bath that does not contain accelerating agents. These appear to be the only published references to special washing procedures following a

Table I

RESULTS OF HUMIDITY TEST

Process	Condition	Washing After Phosphating	Appearance After 2 Months' Test*
I (Iron-phosphate)	Not painted	Washed	Rust in small spots all over
		Not washed	Same as 'washed'
	Painted	Washed	Few random points of rust only
		Not washed	Same as 'washed,' but local loss of paint adhesion in subsequent 'keeping' test
II (Iron-phosphate, non-proprietary)	Not painted	Washed	Slight rust, less spotty than process I
		Not washed	Same as 'washed'
	Painted	Washed	Few random points of rust
		Not washed	Same as 'washed'; also slight rust at zone between crevices and indentation
III (Manganese-phosphate)	Not painted	Washed	Trace of rust at minute spots
		Not washed	Same as 'washed' but brownish 'rusty' zone a short distance from crevices and indentation
	Painted	Washed	No rust
		Not washed	No rust
IV (Zinc-phosphate accelerated)	Not painted	Washed	Rust in small spots all over, heavier rust around pocket-type crevice
		Not washed	Heavy 'wet' rust all over†
	Painted	Washed	Rust and blisters at crevices (*see* Fig. 3)
		Not washed	Heavy rust over much of surface†

* Refers to specimens made from non-oily steel sheet

† The treatment solution added at the indentation produced a complex effect; the central area received protection from rust but away from the centre rust was accentuated

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phosphating process and, although both procedures are expected to help in meeting the washing difficulty occurring with certain joints, their usefulness has not been explored by the present authors.

Although the present tests were fairly severe, the corrosion occurring on specimens treated by processes I–III would be described as only slight: there was almost no tendency to promote rusting, and there was only a slight local interference, if any, with adhesion of paint at points at which appreciable amounts of residual solution would have accumulated. Washing after phosphating overcame this interference, despite the fact that the washing treatment is likely to remove only the bulk ot the residual solution and will not wash out a pocket completely. Results with process IV demonstrated the strongly corrosive nature of this phosphating solution when left on the work. With the type of crevices formed by the overlaps on the specimens, the washing treatment given, although apparently thorough, was not capable of completely removing active material.

The experimental results indicate that, in practice, it is desirable to have a performance test for application to trial components if doubt exists as to the suitability of the process and if it is not known whether the phosphating process to be used is likely to leave corrosive residues, nor whether a particular washing process will satisfactorily remove corrosive residues localized in spot-welded joints or other crevices in the article.

SUGGESTED PERFORMANCE TEST FOR CORROSIVE EFFECT AT JOINTS

The following is a simple test involving exposure of the part to be examined to damp air; any dried-out corrosive residues will tend to absorb moisture and become active.

The finished specimen is suspended in air in a vessel at room temperature, the air being rendered damp by a layer ot water at the bottom of the vessel, which is provided with a loosely fitting lid. The specimen is subsequently examined for signs of rust; a period of test of one week should generally suffice. Absence of rust indicates that corrosive residues are absent or that too little is present to be of practical consequence. Special temperature control appeared unnecessary in a qualitative test of this nature.

Other humidity tests may be used, provided that they are not so severe or prolonged as to produce rusting in the absence of stimulation by the corrosion residues.

A number of sheet-steel specimens, prepared with spot-welded joints, were phosphated, washed, and dried, and were submitted to the above test.

Well-marked rusting, caused by residues of corrosive solution, developed at certain joints. Such residues could be removed by washing but the degree of washing required varied with the type of joint. With joints that did not allow free circulation of washing liquid in them, a double wash with intervening drying was beneficial.

It is considered, in the light of present information, that the test should generally be restricted to use on phosphated parts that have been painted or given some other finishing coating. Its use on phosphated parts before the application of a finishing coating is only recommended for parts of simple shape without joints, since washing treatments may sometimes produce brownish stains at creviced joints, and these stains may be confused with rust forming during the test.

CONCLUSIONS

(1) The risk of corrosion from phosphating solution trapped in crevices or folds is found to vary with the type of phosphating solution. In general, the risk is much less with the plain metal phosphate–phosphoric acid type bath than with accelerated phosphating solutions containing other constituents more active in stimulating corrosion.

(2) With the plain-type bath, washing parts of simple shape, from which solution can drain off freely, is probably not essential, but to avoid the risk of corrosion it is desirable to wash creviced parts after phosphating. It is probable that a relatively simple washing treatment, to remove excess solution (and suspended matter) from recesses or from the mouths of crevices, would be effective. This applies to the iron phosphate and the manganese phosphate processes, but there is no reason to doubt that it also applies to the plain zinc phosphate process, although this has not been specifically tested.

(3) With phosphating solutions containing other active constituents, washing is generally essential to remove residual corrosive solution, particular attention being necessary where crevices are present, possibly on the basis of a simple performance test.

Acknowledgment

Acknowledgment is made to the Chief Scientist, Ministry of Supply, for permission to publish this paper.

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Tentative Analytical Tests for Phosphate Coatings on Steel

By R. St. J. Preston, R. H. Settle, and J. B. L. Worthington

SYNOPSIS

Details of laboratory tests to determine the nature and uniformity of phosphate coatings are given. The tests consist of the measurement of moisture content, absorption, coating weight, hygroscopicity, and the phosphate and chromate contents of the coatings.

LITTLE information is available on tests for the laboratory examination of phosphate coatings. An investigation of tests that might prove useful for specification purposes has been undertaken in collaboration with the Phosphate Coatings Sub-Committee CHE/18/4 of the British Standards Institution. This paper gives details of the tests.

PROPOSED TENTATIVE TESTS

The proposed tests are intended to assist in determining the type and uniformity of a coating, and also the intrinsic protective value of systems incorporating phosphate coatings. The quantities measured are :

(i) Moisture content (loss in weight at 105° C.)
(ii) Absorption value
(iii) Coating weight
(iv) Hygroscopicity
(v) Phosphate content of coating
(vi) Chromate content of coating.

Size of Samples

The specimens or articles used were made of thin-gauge sheet steel. Two flat specimens 6 in. × 4 in., or an equivalent area cut from an article, are required. Strips 4 in. × 1½ in. are cut from each of the specimens, giving four strips, the areas of which are measured to within 0·05 in. When analytical results are given in terms of an area, *e.g.*, coating weight as g./sq. ft., the area used for the calculation is twice that of one face of the sample.

Moisture Content (Loss in Weight at 105° C.)

The four strips are weighed and placed in a thermostatically controlled oven at 105° C. for 2 hr. They are then removed to a desiccator and reweighed when cool ; the mean loss in weight is recorded as a percentage of the coating weight.

Absorption Value

Two of the strips (one from each specimen) used in determining the moisture content are immersed in diacetone alcohol in a 500-ml. tall-form beaker ; about 450 ml. of the liquid are required to cover the specimens. After 2 min., the strips are withdrawn and held over the beaker in a vertical position, shorter edge downwards, and are allowed to drain for 3 min. ; the surplus liquid collecting at the lower edge is absorbed on a piece of filter paper which is passed once along the edge on each side. The specimens are then immediately transferred to weighing bottles and the increase in weight per unit area is determined.

Coating Weight

The two strips used for the determination of absorption are rinsed in distilled water to remove the diacetone alcohol, and are then placed in a beaker containing 15% by weight of sulphuric acid, to which has been added 0·05% of di-orthotolyl thiourea as inhibitor. The removal of the coating is assisted by rubbing ; finally a stiff brush (not of wire) or fine steel wool is used to remove the last traces of coating, and the specimen is immersed in clean water. It is then dried with filter paper or smooth absorbent cloth, placed in an oven at 105° C. for 10 min., cooled in a desiccator, and weighed. The difference between the original weight of the sample (*i.e.* its weight before it was dried for the moisture content determination) and the final weight after stripping is calculated in grams per square foot of surface area, *e.g.*, if an area of $x \times y$ sq. ft. loses a g., the coating wt. is $\frac{a}{2xy}$ g./sq. ft.

Hygroscopicity

The other two strips, one from each sample, after drying and weighing are suspended in a large beaker containing water ; the lower edge of the specimens is approx. 2 in. from the water. The beaker is provided with a close-fitting cover of Perspex, ebonite, or fibre. To ensure a good seal, a piece of ¼-in. dia. rubber tubing, equal in length to the circumference of the rim of the beaker, should be split along its length and the open side of the tube placed over the rim. During the 6-hr. test the beaker is stood in a room where there are no large fluctuations in temperature. The specimens are then quickly transferred to weighed vessels provided with airtight covers, reweighed, and the gain in weight is recorded as a percentage of the coating weight.

Phosphate Content

The reagents required are :

Ammonium Molybdate—A 5% solution in 5*N* sulphuric acid is made up as follows : 50 g. of ammonium molybdate $(NH_4)_6Mo_7O_{24}4H_2O$) are dissolved in

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Mr. Preston and Mr. Worthington are at the Chemical Research Laboratory, Teddington, and Mr. Settle is at the Government Laboratory, London.

about 300 ml. of distilled water in a 600-ml. beaker. This solution is added in small portions to 500 ml. of 10*N* H_2SO_4 in a litre flask, shaking after each addition ; the shaking is continued until the small precipitate formed redissolves. The volume is then made up to 1 litre.

Sodium Sulphite—A solution containing 20 g. of the hydrate ($Na_2SO_3 7H_2O$) in 100 ml. is made up freshly as required.

Sulphuric Acid—12*N* acid is prepared according to density tables given in B.S. 753 : 1937.

Standard Phosphate Solution—A standard phosphate solution is prepared by dissolving 5·582 g. of anhydrous potassium dihydrogen phosphate (A.R. grade) in water, and diluting to 250 ml. A 10-ml. fraction of this solution is then diluted to 1000 ml. : the amount of this solution to be taken for comparison with the solution being estimated varies with the concentration of phosphate in the latter, and should be chosen to obtain as close a colour match as possible. The approximate quantities of standard and unknown solutions required for the titration are as follows :

Coating wt., g./sq. ft.	Amount of Solution, ml. Standard	Unknown
0·5	10	25
1	20	25
2	40	25
3	50	20
4	50	15
5	40	10
6	50	10

Other convenient strengths and aliquot portions of the solutions may be used but the standard and unknown phosphate contents must be within 10–15 % of each other.

The two test pieces used in the determination of hygroscopicity are put into two beakers, each of which contains 150 ml. of *N* HCl. The coating is removed by rubbing with a glass rod protected with a piece of close-fitting rubber tubing. The stripped specimens are washed with distilled water, using not more than 50 ml., and the solution is finally made up to the mark in two 250-ml. standard flasks.

The required volumes of standard phosphate solution and of solution containing the stripped phosphate coating are put into separate 100-ml. flasks. Three drops of phenolphthalein solution are added to each, and the solution containing the stripped phosphate coating is neutralized with approx. *N* NaOH. The same quantity of *N* NaOH is added to the standard solution which is then neutralized by the addition of *N* HCl. Both solutions are diluted to a volume in excess of 60 ml., and 5 ml. of 12*N* H_2SO_4 (or its equivalent) are added. 8 ml. of ammonium molybdate, 4 ml. of sodium sulphite, and 4 ml. of hydroquinone are added in that order, the flask being shaken after each addition.

Both solutions are made up to 100 ml., and stoppered ; the flasks are immersed to the mark in a water bath at a temperature of approx. 60 ± 5° C. They are removed from the bath after about ½hr., cooled to room temperature, and the depth of colour of the two solutions is compared. The comparison should preferably be made on a colorimeter, but if this is not available, Nessler tubes may be used, the stronger solution being diluted until a match is obtained. Duplicate determinations should lie within ± 2½% of the mean value. The proportion of phosphate (PO_4'') in the coating is given as a percentage of the coating weight previously determined.

Chromate Content

The remaining two test pieces are stripped by dissolving the coating in about 15 ml. of 1 : 3 H_2SO_4, diluted with 20 ml. of water. The stripped specimens are removed and rinsed ; the washings are added to the solution, which is then treated with 5 ml. of HNO_3 (sp. gr. 1·2) and boiled until free from nitrous fumes. After cooling, the solution is transferred to a graduated 250-ml. flask and made up to the mark with distilled water.

50 ml. of this solution are then transferred to a beaker, oxidized with three drops of saturated potassium permanganate solution, boiled for a few min. and the excess permanganate is reduced by the dropwise addition of concentrated HCl until the solution is clear ; generally 30–50 drops are required.

The clear solution is immediately cooled, and the iron is precipitated by the addition of saturated $NaCO_3$ solution. The solution with precipitate is transferred to a 100-ml. graduated flask, diluted to the mark with water, and filtered. A suitable aliquot part of the clear filtrate is placed in a 100-ml. Nessler cylinder, acidified with 20 ml. of H_2SO_4 solution (1 : 3), and 5 ml. of a 0·1% solution of diphenyl carbazide are added. Into a second 100-ml. Nessler cylinder are placed 20 ml. of H_2SO_4 (1 : 3), and 5 ml. of the same solution of diphenyl carbazide together with sufficient water to bring the total volume nearly equal to that in the first cylinder. A solution of *N*/1000 potassium dichromate is then added to the second cylinder, until a colour match is obtained. From the volume of *N*/1000 dichromate solution required, the precentage of chromic acid (CrO_3) in the coating weight can be calculated.

1 ml. of *N*/1000 potassium dichromate is equivalent to 0·0000333 of CrO_3.

Acknowledgments

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Fluidity and Solidification Tests for Molten Steels

By W. Ruff, Dr. Ing.

SYNOPSIS

The mould design used in earlier work on fluidity tests was modified during the war because of the restriction on the use of dextrin as a bond for moulding sand. With the new design the length of run cannot be measured, but the weight of metal flowing out of the mould orifice before solidification is taken as a measure of fluidity.

A mould with a 400-mm. channel length and a 5-mm. channel diameter is shown to give information on the mechanism of flow, but none of the moulds examined is suitable for fluidity estimations.

For the control of steelmaking processes, an accurate method of determining the temperature of molten samples when solidification starts is required: a new pot mould, in which the channel is discarded, provides a sensitive sampling method that requires no built-in measuring instrument.

In an earlier paper,[1] the author, working with nickel-free and nickel-containing chromium–molybdenum steels, has shown the value of the casting test utilizing a long straight channel as a measure of fluidity.[2, 3] By testing the molten steel it was possible to produce forgings with improved mechanical properties. The present paper presents further work on similar lines, which has been carried out at the Mitteldeutsche Stahlwerke in Groditz, near Riesa.

A practical application of the results of the earlier work was the determination of the length of run for fluidity tests. For the molten steel being considered, the results of mechanical tests on some of the final forgings were unacceptable, and duplicate tests had to be made. These were compared with the fluidity tests (*see* Table I) and showed clearly that the number of duplicate tests required is reduced as the fluidity increases. From this information it is possible to establish an optimum length of run in the fluidity test, thus protecting the furnace from excessive overheating.

FLUIDITY TESTS

During the last war, the use of dextrin as a bond for moulding sand was restricted, and fluidity tests could not be continued in their original form because, with a substitute bonding material, the original channel length of 720 mm. was too long to give reliable results. Three modified test moulds, *A*, *B*, and *C*, were designed; their characteristics were as follows:

	A	*B*	*C*
Channel length, mm.	200	300	400
Channel diameter, mm.	4	5	5

With these moulds the length of run could not be measured, but the weight of metal flowing out of the mould orifice (the outflow weight) was used as an indication of fluidity.

With the earlier type of mould, reheating after testing was necessary with about 13% of the melts. In the outflow tests using the modified moulds, the proportion of melts that required reheating was approximately the same with moulds *A* and *C*, but was greater with mould *B*. The results of outflow tests on two consecutive samples, I and II, on 20-ton basic electric furnace melts are given in Table II. Only with mould *C* were the results sufficiently accurate to show any correlation between the pouring temperature reached after tapping and the outflow weight. The results of tests on a Cr–Ni–V steel containing 0·43% C, 0·58% Mn, 1·75% Cr, 1·25% Ni, and 0·12% V, using mould *C* with a maximum reheating time of 9 min., are given in Table III and Fig. 1.

Outflow tests on a Cr–Mo steel using mould *C* showed that the addition of 0·7% of Ni to the steel did not affect its flow characteristics. The nickel content of the steels used in the earlier work[1] was 2·35%, but because of wartime restrictions this was reduced to 0·7% in the present work.

TIME STUDIES WITH A SLOW-MOTION CAMERA

Rate of Flow

With the three moulds *A*, *B*, and *C*, a slow-motion ciné-camera capable of taking 64 exposures per sec. was used to determine the time taken (*a*) for the ingate to overflow (the ingate filling time), (*b*) from the disappearance of the first drop of liquid steel down the ingate to its appearance at the exit from the channel (the running time), (*c*) from the appearance

Table I

NUMBER OF DUPLICATE TESTS IN RELATION TO LENGTH OF TEST RUN

	No. of Melts	No. of Duplicate Samples	No. of Duplicate Samples per Melt	Mean Length of Run, mm.
Cr–Mo steels	70	107	1·54	432·5
	66	87	1·32	462·5
	66	65	0·98	492·5
	33	15	0·46	522·5
	17	11	0·65	552·5
	9	4	0·44	582·5
Cr–Ni–No steels	15	23	1·53	522·5
	13	12	0·92	552·5
	9	1	0·11	582·5

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of the first drop at the channel orifice to the last drop flowing out of the channel (the outflow time). The results obtained with slow-motion films of 34 tests are given in Table IV.

Calculations

By introducing the following modifications, three examples have been used to calculate the retarding effects :[4]

(i) The viscosity of malleable cast iron ($\eta = 0{\cdot}019$ dynes sec./sq. cm.) has been used instead of that for the viscosity of steel

(ii) A reduction of 0·8 mm. in the channel diameter has been assumed because metallic crystals are formed on its walls

(iii) A resistance coefficient λ (wall friction) of 0·016 has been used, as in the earlier tests on malleable cast iron.

The deceleration a was calculated from these values.

Mean Outflow Velocity V—This velocity is calculated from the mean outflow weight and the mean outflow time T, assuming the specific gravity of liquid steel to be 6·94 g./c.c.

Reynolds' Number R—This Number is calculated from the equation $R = vd/\nu$, where d is the channel diameter in cm., v is the mean velocity before outflow, and ν is the kinematic viscosity ($0{\cdot}375 \times 10^{-2}$ sq. cm./sec. for steel, and $0{\cdot}276 \times 10^{-2}$ sq. cm./sec. for malleable cast iron).[5]

Deceleration a—This is obtained from the resistance coefficient λ from the equation

$$a = \frac{v^2\lambda}{2d},$$

where d is the channel diameter in cm.

Initial Flow Velocity Before Outflow V_0—This velocity is calculated, by applying Newton's law of uniformly decelerated motion, from the equation

$$d = v_0 t - \frac{a}{2}t^2,$$

where t is the mean running time.

By differentiation,

$$V_0 = v_0 - at,$$

where V_0 is the initial outflow velocity.

DISCUSSION OF RESULTS

Pouring Conditions

The outflow weights obtained largely depend on the filling time of the feeder head. Tests may be divided into 'good' and 'bad,' according to whether the filling time is long or short.

With mould *C*, the difference in the outflow weights is only 25% for a 50% difference in filling time. The effect of filling time on outflow weight, however, is greater with moulds *A* and *B*. With a short running time (mould *A*) the test results are affected by the pressure head of the liquid metal ; if the ingate filling time is too long, as in badly poured tests, the outflow time and outflow weight are too small. From a total of 42 pairs of duplicate samples, the outflow weight of the first sample was in 32 cases higher than that of the second sample, because in most cases the second sample was poured more slowly. With mould *B* a smaller proportion of first samples had a higher outflow weight. With this mould the ingate was sometimes filled before the molten steel reached the

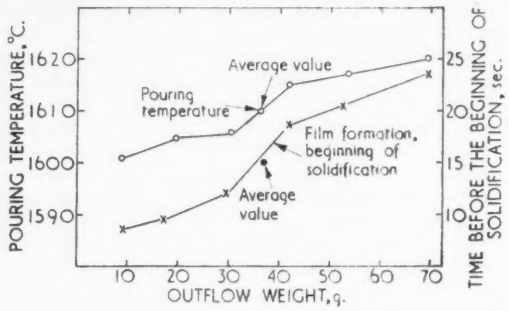

Fig. 1—Outflow tests on Cr–Ni–V steel, using mould *C*

Table II

RESULTS OF OUTFLOW TESTS USING MODIFIED MOULDS

Details of Test	Moulds		
	A	*B*	*C*
Range of outflow weights, g.	13–47	37–1400	8–85
Average outflow weight, g.	28 ± 6·2	222 ± 108	35 ± 6·9
No. of samples taken	42	43	330
No. of melts reheated	6	10	44
Percentage of melts reheated	14·3	23·2	13·3
Average reheating time, min.	14	16	15
No. of times outflow weight of sample I exceeded that of sample II	32	25	140

Table III

RELATION BETWEEN POURING TEMPERATURE AND OUTFLOW WEIGHT

No. of Melts	2	12	43	20	13	7
Mean casting temp., °C.	1601	1605	1606	1615	1617	1620
Mean time before tapping, min.	4	6	6	5	5	4
Range of outflow weight, g.	0–12	12–24	24–36	36–48	48–60	760
Mean outflow weight, g.	9·0	19·5	30·3	41·8	53·8	69·5

end of the channel, thereby reducing the pressure head and thus slowing down the rate of flow. Shorter filling time, however, generally leads to a higher outflow weight (*see* Table IV).

Rates of Entry and Exit

With mould C, although the ingate filling times differ, the mean outflow velocity of all samples (5 'bad' and 9 'good'), calculated from the mean outflow time and mean outflow weight, was the same (*see* Table IV). This may be explained by the almost identical running times before outflow of the 'good' and 'bad' samples. It may therefore be concluded that, with a type C mould, the low sensitivity to variation in filling time is caused by the equalizing effect of the flow velocities when pouring commences. The mean outflow velocity is less than the mean velocity before outflow except in the case of the 'good' samples with mould B. In these tests the outflow weights and outflow times were very high, indicating that the outflow velocity may increase with increasing outflow time. From the figures given in Table IV, the mean outflow velocity is 22·6% greater than the velocity before outflow. In the tests reported in Table IV the outflow velocity is less than the entry velocity, but if the steel entering the mould has to overcome large obstacles, such as solid particles and gases from the moulds, before a normal flow is built up, the outflow velocity may exceed the entry rate. A comparison of the initial outflow velocity V_0 with the mean outflow velocity V shows that, with the exception of the 'bad' samples with moulds A and the 'good' samples with mould B, $V_0 > V$. With mould A, the low value of V_0 was caused by the small channel diameter together with the long ingate filling time; with mould B the high outflow weight was caused by an increase in outflow velocity and in outflow time. The results of tests with mould C show that the initial flow velocity (approx. 46 cm./sec.) was about 18% higher than the mean outflow velocity.

Effect of Reduced Viscosity

Values for deceleration and retarding effect show that with decreasing viscosity the fluidity of the metal may decrease as a result of greater turbulence. For a decrease in viscosity from 0·026 to 0·019 dynes sec./sq. cm., the deceleration a increases by approx. 9%.

Effect of Channel Diameter

It was assumed that a considerable thickness of metal solidified on the channel walls, causing a reduction in diameter. The retarding effect α_δ was between 13% and 16% for decreases in channel cross-section of 36% and 29·4%, except in the case of mould A 'bad' samples.

Table IV

CALCULATION OF FLOW VELOCITY AND RETARDING EFFECTS

Channel Diameter, mm.	Mould *A*		Mould *B*		Mould *C*	
	4		5		5	
Experimental						
Casting quality	Bad	Good	Bad	Good	Bad	Good
No. of duplicate samples	7	6	3	4	5	9
Mean outflow weight, g.	20	35	68	739	27	36
Mean ingate filling time, sec.	0·94	0·43	1·18	0·66	0·95	0·63
Mean running time t, sec.	0·42	0·26	0·50	0·39	0·51	0·50
Mean outflow time T, sec.	0·55	0·82	1·23	5·73	0·52	0·68
Calculated						
Mean outflow velocity V, cm./sec.	41·7	49·0	40·6	94·4	38·9	38·9
Mean velocity before outflow v, cm./sec.	47·7	77·0	60·0	77·0	78·5	80·0
Reynolds' No. R (η=0·026 dynes sec./sq. cm.)	5100	8200	8000	10,280	10,480	10,680
Resistance coefficient λ (—ditto—)	0·0185	0·0205	0·0205	0·0210	0·0210	0·0210
Mean deceleration a, cm./sec./sec.	52·7	151·9	73·8	124·5	129·4	134·4
Rate of entry, cm./sec.	58·7	96·7	78·5	101·2	111·4	113·6
Initial outflow velocity V_0, cm./sec.	36·6	57·2	41·6	52·6	45·4	46·4
Retardation by viscosity ($\eta = 0{\cdot}019$ dynes sec./sq. cm.)						
Reynolds' No. R	6900	11,140	10,870	13,950	14,200	14,500
Resistance coefficient λ	0·0200	0·0220	0·0215	0·0230	0·0230	0·0230
Mean deceleration a, cm./sec./sec.	56·9	163·1	77·4	136·4	141·7	147·2
Retarding effect α_η, %	+8·0	+6·9	+4·9	+9·6	+9·5	+9·5
Retardation by size of channel diameter						
Dia. of channel, mm.	3·2	3·2	4·2	4·2	4·2	4·2
Reynolds' No. R	4070	6570	6720	8620	8800	8970
Resistance coefficient λ	0·0175	0·0190	0·0195	0·0205	0·0205	0·0205
Mean deceleration a, cm./sec./sec.	75·9	176·0	83·6	144·7	150·4	156·2
Retarding effect α_δ, %	+44·0	+13·7	13·2	16·2	16·2	16·2
Retardation by wall friction ($\lambda = 0{\cdot}016$)						
Mean deceleration a, cm./sec./sec.	45·5	118·6	57·6	94·9	98·6	102·4
Retarding effect α_λ, %	−13·6	−21·3	−22·0	−23·8	−23·8	−23·8

Table V

RELATION BETWEEN OUTFLOW WEIGHT AND TIME WHEN SOLIDIFICATION STARTS

							Mean
No. of melts	1	17	58	44	22	6	...
Mean time before tapping, min.	4	9·5	6·8	9·0	7·4	5	7·8
Range of outflow weights, g.	0–12	12–24	24–36	36–48	48–60	>60	36
Mean outflow weight, g.	9·0	17·6	29·4	41·2	53·0	69·1	36·5
Mean time before start of solidification, sec.	7	13·5	17·1	20·7	22·2	26·8	18·8

Effect of Resistance Coefficient

To increase appreciably the fluidity of a metal the only method, apart from that of raising its temperature, is to lower the resistance coefficient λ. In calculating the deceleration (Table IV), a value of 0·016 was assumed for λ (a decrease of about 0·005), and this lowered the deceleration by about 24%. The assumed value for λ had been obtained experimentally for malleable cast iron.[4]

CONCLUSIONS

Since the results given in Table IV show that wall friction is the main factor affecting fluidity, it is useless to use a shorter running-capacity test mould, since each drop of steel flowing out of the mould channel represents a loss of potential wall friction, and the measurement of the channel is thereby reduced. Mould-outflow tests are not, therefore, suitable for determining fluidity. The earlier long test-mould technique, in which steel does not flow out into the open, appears to be the best method yet developed for fluidity determinations.

The values of α_λ, the retarding effect due to reduced wall friction, indicate that the flow resistance of the metal in the mould is influenced mainly by the nature of the crystals deposited on the wall (cubic, spherical, or needle-like), rather than by the actual surface of the mould. The author has previously shown[4] that, at normal pouring temperatures, the metal is separated from the surface by a wall of small metallic crystals.

SOLIDIFICATION TESTS

The restrictions on the use of alloying elements during the war diminished the importance of fluidity testing because the fluidity of the available steels varied only slightly. An accurate method of determining the temperature of samples of molten steel therefore became the foremost problem in controlling steelmaking processes.

The spoon sample method, in which the glare on the surface of the steel gives an indication of the temperature, was used. This method has the following disadvantages :

(i) Because of the variations in the slagging of the spoon, the cooling conditions of the steel are not reproducible

(ii) The area of steel surface free from slag varies for each sample

(iii) The weight of sample varies with its volume and with the method of dipping and slagging

(iv) The moment at which the film starts to form on the liquid surface has not been accurately determined.

These disadvantages were overcome by emptying the contents of the sampling spoon into the ingate of the casting test mould before noting the time. The results of tests with mould type *C* are given in Fig. 1 and Table V. The author considers that the skin, known to form on liquid steel, consists of crystals, which appear at the liquidus, and that complete solidification follows at the solidus after a definite interval. This is contrary to the view held by some workers[6] that the skin consists solely of an oxide film. It has not been shown, however, that the surface tension of the oxides formed is sufficiently high at the temperature of liquid steel to permit the formation of a coherent skin before the steel solidifies.

The curves plotted in Fig. 1 are almost parallel, suggesting that, if fluidity is disregarded, mould *C* may be used without the channel for comparative temperature determinations. The preliminary tests

Table VI

SOLIDIFICATION TESTS ON CR–NI–V STEELS USING THE NEW POT MOULD

	Range of Time Intervals, sec.	Start of Solidification						End of Solidification					
		15–20	20–25	25–30	30–35	35–40	Mean 27·5	30–35	35–40	40–45	45–50	50–55	Mean 42·5
1st Series (Mean time before tapping 6·2 min.)	No. of samples	15	37	51	19	8	...	9	40	47	27	7	...
	Mean time, sec.	17·4	22·9	26·7	31·2	36·2	25·8	33·0	37·0	41·8	46·5	53·3	41·3
	Mean temperature, °C.	1601	1606	1606	1610	1615	1607	1600	1605	1607	1610	1613	1606
2nd Series (Mean time before tapping 8·2 min.)	No. of samples	8	9	15	24	...	...	9	6	17	24	...	...
	Mean time, sec.	17·2	23·3	27·6	31·8	...	27·1	32·3	37·8	44·5	47·3	...	42·2
	Mean temperature, °C.	1596	1602	1602	1604	...	1602	1597	1600	1603	1604	...	1602

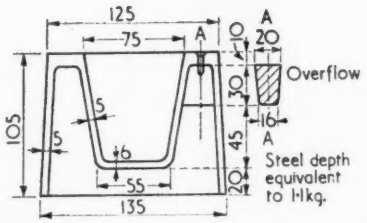

Fig. 2—Section of pot mould. Measurements in mm.

showed that time interval measurements were very accurate, and only a single test was necessary : the maximum difference for two consecutive samples was 3 sec., and the mean difference was 1·2 sec.

THE NEW POT MOULD

As a result of these preliminary experiments on the solidification time of the outflow samples in the ingate, a new pot mould was designed. The details of the mould are given in Fig. 2. The pot can hold 1·1 kg. of liquid steel from a sampling spoon of about twice this capacity. A wide ring protects the steel from draughts, and a large overflow provides for the excess steel. The mould is prepared from material containing large amounts of clay and chamotte ; it is surface-dressed, and is fired at 500–600° C.

One sample only was taken for each test. As a control, the time taken for the steel to freeze completely was also noted with a stopwatch. When a 1-mm. dia. wire would no longer penetrate the surface of the mould, solidification was assumed to be complete. The surface was not tested more than once at the same point, so as to avoid erroneous results caused by hot steel rising from the bottom of the pot.

The results of two series of tests on Cr–Ni–V steels with the new mould are given in Table VI. The first series was carried out 3–4 months before the second series. The rates of change of casting temperature with time at the start and at the end of crystallization were approximately the same for both series of tests, but the mean casting temperature of the first series was about 4° C. higher. The author has shown that pouring temperature increases with increased overheating, but in the two series of tests reported, there was less overheating in the tests with the lower casting temperature. The difference in casting temperature was, therefore, attributed to an error in the colour pyrometer (Bioptix) used for the temperature measurements. During the experiments the instrument was only occasionally calibrated : continuous calibration is necessary for accurate measurement.

The results in Table VI, however, show that the new pot mould provides a sensitive sampling method that is cheap, simple, and requires no built-in measuring instrument.

Acknowledgments

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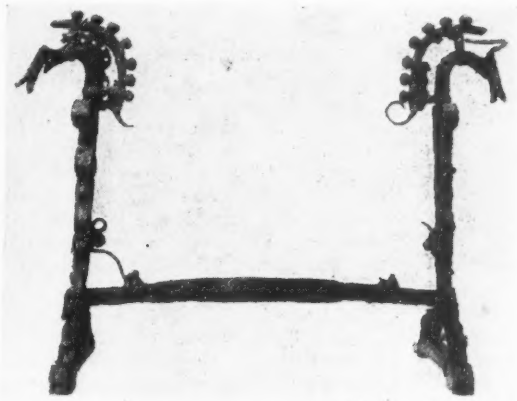
HISTORICAL NOTE NO. 26

A Romano-British Firedog

By Dr. H. R. Schubert



The firedog illustrated above was discovered at Capel Garmon in Denbighshire in 1852. By its elaborate ornamentation the firedog represents a fine work of art produced by a Welsh smith at the beginning of the Christian era. The wrought-iron firedog was designed for the central hearth of the hall. The two uprights, standing on arched feet and joined by a cross-bar, were made of square bars and were bent outwards at the top in the form of a horned animal's head. A mane was formed by a row of knobs at the outer edge. The sides have iron bands attached to them and these are bent into loops which were intended to hold spits for roasting ; larger spits were held by the horns of the head. The lowest loops are just above the arched feet. Because of the position of the loops, each could be used in turn according to the nature of the cooking and the height of the fire.*

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* J. C. Peake, "The Double-ended Firedog," *Antiquity*, 1942, Mar. p. 64.

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Preferred Grain Orientation in Steel Castings

By J. D. Lavender and J. I. Morley, A.I.M.

SYNOPSIS

The preferred orientation of the columnar grains in steel castings is considered in relation to the allotropic transformations that occur during cooling. Where these transformations occur at very high temperatures, of the order of 1300° C., as in certain stainless steels, the crystallographic orientation of the primary dendrites is preserved at room temperature, and columnar-grained castings will then be subject to elastic anisotropy. Where they occur at temperatures of 700° C. and below, as for example in mild steel, a random orientation is developed during re-crystallization, and a test on a columnar-grained specimen of mild steel suggests that such castings will be elastically isotropic.

In 1929, Nix and Schmid[1] confirmed the existence of preferred orientation in columnar-grained castings of an iron–silicon alloy by X-ray methods. This orientation was such that a [100] direction of the columnar crystals was perpendicular to the mould walls.

More recently, one of the present authors has observed that a similar orientation of the columnar grains in centrifugally cast rings of certain austenitic steels is responsible for the low values of elastic modulus in test pieces cut transversely to the length of the crystals.[2] Similar low values of about 10,000 tons/sq. in. have also been obtained in a direction parallel to the columnar grains. Both test pieces were stressed in line with a [100] direction of the crystals. It is reasonable to suppose that higher values of Young's modulus would be obtained in the [110] and [111] crystallographic directions.

These effects were observed in castings of 18/8 Cr–Ni–Ti, 18/12 Cr–Ni–Nb, and 25/12 Cr–Ni–W, all of which are essentially austenitic at room temperature.[2] The first of these steels, however, solidified substantially as delta ferrite and experienced a transformation to austenite during cooling to room temperature. The second steel solidified as austenite and did not subsequently transform. The third steel was intermediate in character—as-solidified about 30% ferrite was present, which transformed to austenite during cooling.

In all three steels, the columnar austenite grains at room temperature were oriented with a cube face parallel to the mould wall, although in the 18/8 Cr–Ni–Ti steel, as indicated above, the primary solidification was delta ferrite. If the formation of columnar grains in castings is attributed to anisotropic rates of crystal growth, it can be assumed that the columnar ferrite grains, which existed at high temperatures immediately after solidification, would also be oriented with respect to the temperature gradient in the solidifying casting. This could not easily be checked nor could the type of orientation of the primary ferrite grains be ascertained owing to the difficulty of retaining in the steels any substantial quantity of the high-temperature ferrite at room temperature. If, however, the crystallographic orientation of the primary ferrite grains is similar to that observed in the corresponding austenite grains at room temperature, then it would appear either that the transformation from a body-centred to a face-centred cubic lattice occurs without recrystallization or that any new crystals have the same preferred orientation.

These considerations led to a brief investigation of the nature of the preferred orientation in similar steels that retain primary ferrite at room temperature and in low-alloy steels in which a transformation occurs during cooling from high-temperature austenite to low-temperature ferrite.*

MATERIALS AND METHOD

Castings consisting of an outer zone of columnar crystals and an inner zone of equiaxed crystals were used. The steels had different transformation characteristics and their cast analyses are given in Table I.

Specimens of steels *A*, *B*, and *E* were examined as-cast without heat-treatment; steels *C* and *D* were tempered at 650° C. The size of the castings and the type of transformation that is known to occur during cooling, are indicated in Table II.

Small cylinders, $\frac{1}{4}$ in. dia. × $\frac{1}{2}$ in. long, each with a small central hole, were machined from the columnar and equiaxed regions of the castings. The specimens were drastically etched to remove cold-work from the surface. Photographs of etched specimens of steels *A* and *C* (*see* Fig. 1) show the equiaxed grains, having a random distribution over the specimen, and the columnar grains, which run in the direction of the axis of the cylinders. The specimens were positioned at the end of a long rod to facilitate rotation in the X-ray

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* Two of these low-alloy steels have relatively high carbon contents and are therefore free from delta ferrite at all temperatures.

Table I—CAST ANALYSES OF STEELS

Steel	C, %	Si, %	Mn, %	Cr, %	Ni, %	Mo, %	W, %	V, %	Fe, %	N_2 %
A	0·21	1·85	0·70	25·20	11·70	...	3·20	...	Balance	...
B	0·028	0·17	0·66	21·20	0·13	...	...	...	,,	0·010
C	0·50	0·66	0·84	1·43	0·21	0·43	...	0·28	,,	...
D	0·71	0·14	1·98	...	...	...	...	...	,,	...
E	0·15	0·05	0·14	tr.	0·05	0·03	...	...	,,	...

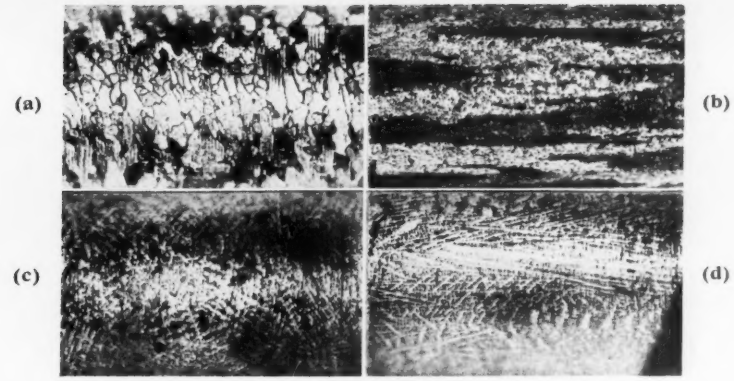


Fig. 1—Photographs of etched specimens used for X-ray examination showing: (*a*) Equiaxed grains, steel *A*; (*b*) columnar grains, steel *A*; (*c*) equiaxed grains, steel *C*; (*d*) columnar grains, steel *C*

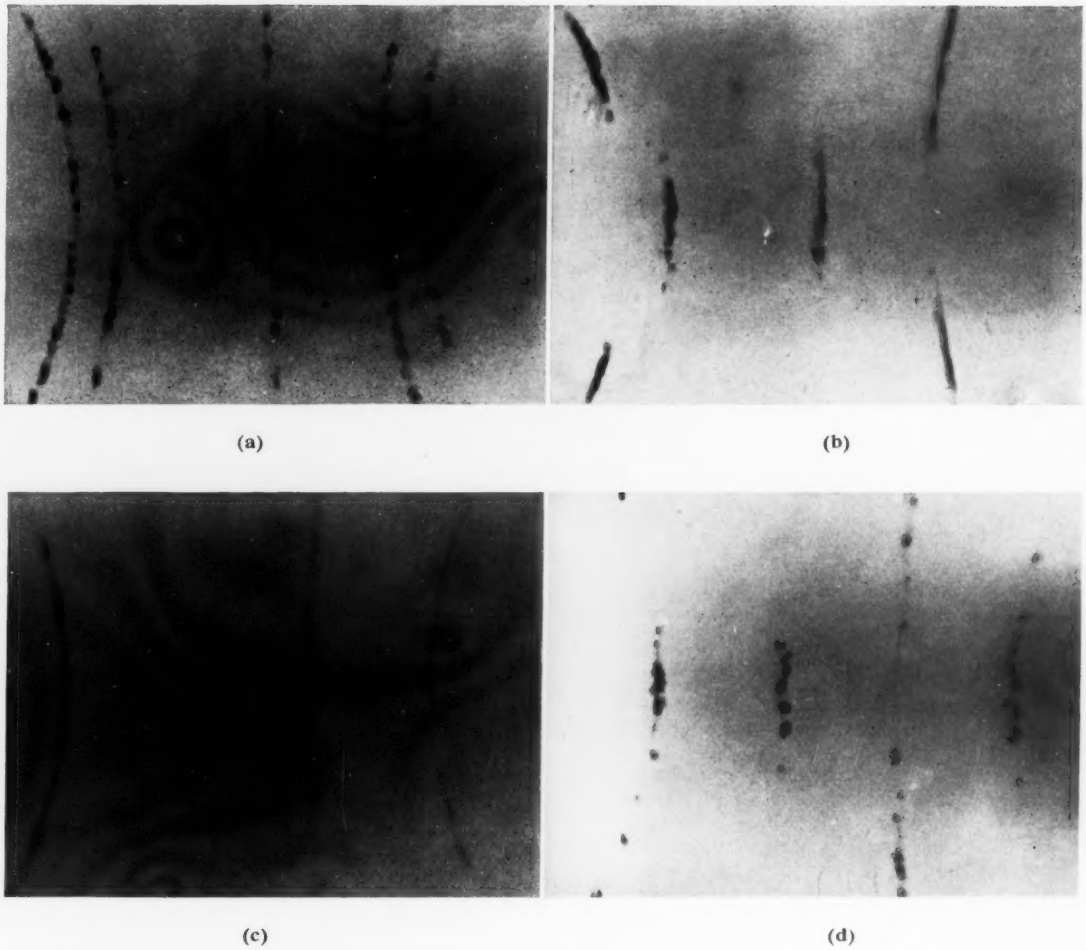
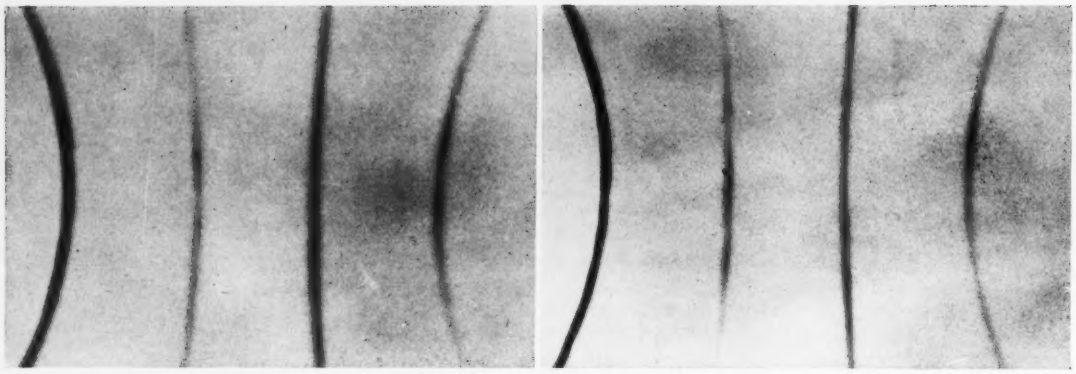
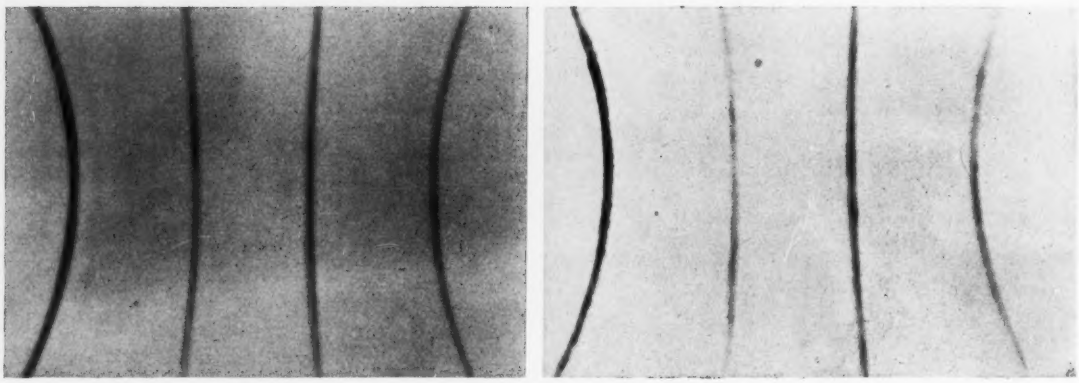


Fig. 2—X-ray photographs showing: (*a*) Equiaxed grains, steel *A*; (*b*) columnar grains, steel *A*; (*c*) equiaxed grains, steel *B*; (*d*) columnar grains, steel *B*



(a) (b)

Fig. 3—X-ray photographs of steel *C* showing : (*a*) Equiaxed grains ; (*b*) columnar grains



(a) (b)

Fig. 4—X-ray photographs showing columnar grains : (*a*) Steel *D* ; (*b*) steel *E*

Table II
DETAILS OF CASTINGS

Steel	Size of Casting	Microstructure			Temp. Range of Transformation
		Immediately After Solidification	At Room Temperature	Principal Type of Transformation	
A	Centrispun die-cast ring, 24-in. outside dia., 3-in. thick wall	Mainly α	$\gamma + \alpha +$ (σ and carbides)	$\alpha \rightarrow \gamma$	1350°–1100° C.
B	2½-in. square ingot	α	α	None	...
C	2½-in. square ingot	γ	Bainite and martensite	$\gamma \rightarrow \alpha$	Below 750° C.
D	2½-in. square ingot	γ	Ferrite and bainite	$\gamma \rightarrow \alpha$	Below 750° C.
E	2½-in. square ingot	Mainly γ	Ferrite and carbide	$\gamma \rightarrow \alpha$	Below 750° C.

beam and were examined using the grazing incidence technique and CoKα radiation.

RESULTS OF TESTS ON HIGHLY-ALLOYED STEELS

Figures 2*a* and *c* reproduce the X-ray photographs obtained from the equiaxed grained specimens of steels *A* and *B*; the normal face-centred cubic structure of the austenitic steel *A* and the body-centred cubic structure of the ferritic steel *B*, are revealed. Since the specimens were rotated during the examination, many grains are represented, in spite of the relatively large grain size of the original castings. The photographs indicate that the crystallographic orientation of these grains is random with respect to the axis of rotation. These specimens were machined from the castings such that the axis of rotation was in the length direction of the ingot, in the case of steel *B*, and in the axial direction of the cylinder, in the case of steel *A*. As shown in Fig. 1*a*, etching revealed that, even in the equiaxed grain zone, *i.e.*, remote from the chilled skin, many of the grains appeared to be rather elongated on the surface. Although this did not necessarily indicate a departure from equiaxed crystallization, it was decided to examine other specimens cut from the equiaxed grains in a direction perpendicular to the chilled skin. This was done for steels *A* and *B*, but again there was no evidence of any preferred orientation. Figures 2*b* and 2*d* illustrate the X-ray photographs given by the columnar grains of the austenitic steel *A* and the ferritic steel *B* when rotated about an axis perpendicular to the chilled skin. Both show preferred orientation.

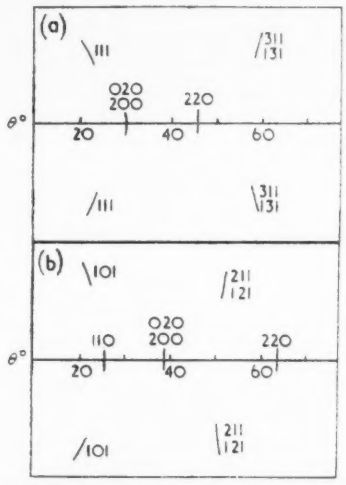


Fig. 5—Theoretical values for positions of *h k l* reflections for preferred orientation on the 100 plane : (*a*) Face-centred lattice ($a_0 = 3{\cdot}59$ Å) ; (*b*) body-centred lattice ($a_0 = 2{\cdot}86$ Å). Camera radius 4·5 cm.

The positions of reflections for single crystals rotating about an axis perpendicular to a [100] direction were calculated. The result for a face-centred cubic structure and for a body-centred cubic structure is shown in Fig. 5. These and the X-ray photographs of Figs. 2*b* and 2*d*, correspond sufficiently to indicate that the columnar grains in both the austenitic and the ferritic steels lie with their cubic faces parallel to the outer chilled skin of the castings. The lack of perfect agreement, in that line blackening is more extensive than it would be for a single crystal, indicates that the [100] crystallographic directions of individual grains are appreciably scattered about a mean value corresponding to the perpendicular to the mould wall. Calculations suggest that this scatter occurred through an angle of $+ 8°$.*

Thus, steel *B*, in which the primary solidification is body-centred cubic and which undergoes no transformation on cooling, exhibits columnar grains having a marked degree of preferred orientation. Steel *A*, in which the columnar grain solidification is also substantially body-centred cubic ferrite, but which quickly transforms to face-centred cubic austenite at very high temperatures during cooling, is also subject to a similar preferred orientation. A third case is provided by the 18/12 Cr–Ni–Nb steel referred

* This estimate takes no account of the possibility that the mean orientation of the grains may be slightly inclined to the perpendicular from the mould wall and hence to the axis of the specimen. It therefore indicates an upper limit to the spread of individual crystal orientations.

to in a previous paper.[2] In this steel, the columnar austenitic grains which freeze from the melt are also stable at room temperature. These are also oriented in such a way that a [100] direction lies perpendicular to the mould wall.

The common feature of the three steels is their high chromium content. The differences in primary solidification result from the varying ratios of nickel to the ferrite-forming elements silicon, tungsten, niobium, and to chromium. Because one steel, which retains highly-alloyed delta ferrite at room temperature, has columnar ferrite grains with preferred orientation, and another, which transforms from highly-alloyed ferrite to austenite during cooling, have the same preferred orientation, it may be inferred that the transformation from body-centred to face-centred cubic structures takes place without disordering the crystallographic orientation of the primary grains.

RESULTS OF TESTS ON LOW-ALLOY STEELS

In the above highly-alloyed steels, either there is no transformation, or it occurs at high temperatures during cooling. Ferritic steel castings, which solidify as austenite but transform to ferrite at temperatures below 750° C., were therefore examined: two small ingots each containing both columnar and equiaxed grains were used for this purpose. Figures 1*c* and *d* illustrate the deeply etched surfaces of the specimens machined from the ingot of steel *C*. The crystallization is revealed by the dendritic formations rather than by grain contrast but, as with the high-alloy steels, the columnar grains lie in the length direction of small cylindrical specimens. Figure 3 shows the X-ray photographs of the columnar and equiaxed grains of steel *C*. These have the structure of the body-centred cubic ferrite resulting from the tempered bainitic and martensitic structures of the original cast ingot. As would be expected, there is no preferred orientation in the equiaxed grains (Fig. 3*a*); the columnar-grained specimen (Fig. 3*b*) has, however, also given almost uniform line blackening. These results may be influenced to some extent by the tempering; the diffusionless martensitic transformation of columnar austenitic grains at low temperatures has not been investigated.

Similar results were given by the two specimens of steel *D*, in which the transformation was essentially bainitic, and also by the two specimens of the mild steel *E*, in which a pearlitic type of transformation, *i.e.*, a transformation to ferrite and carbide at about 600° C., occurred, and which required no tempering prior to sectioning the ingot. For both steels *D* and *E*, the columnar grains gave almost uniform line blackening, indicating the absence of preferred orientation. The corresponding X-ray photographs are reproduced in Fig. 4.

It may be assumed that the primary austenite columnar crystals of the low-alloyed steels *C*, *D*, and *E*, as shown, for example, by the dendrites in Fig. 1*d*, were originally oriented in the same way as the corresponding stable austenite grains in the casting of 18/12 Cr–Ni–Nb.[2] This is also consistent with the work of Northcott[3], who established the relation between the dendritic structure and the grain orientation of several cast copper alloys. Hence the transformation from austenite to ferrite, which in this case occurs at temperatures below 750° C., must involve the destruction of the original crystallographic orientation of the columnar grains. This is associated with the recrystallization of austenite to ferrite which, with the original spread in the preferred orientation of the austenite grains, results in almost random orientation. The persistence of the columnar dendrites in the etched structures, in spite of the subsequent recrystallization, is due presumably to micro-segregation. The cast iron–silicon alloy, in which Nix and Schmid[1] observed preferred orientation of the columnar grains, although ferritic at room temperature, did not undergo transformation during cooling, since its silicon content of 4·3% effectively suppressed the change from delta to gamma iron. This alloy was similar to steel *B* used in the present investigation.

Tests carried out on a columnar-grained specimen machined from an ingot of the mild steel *E* showed that the hardness (as-cast) was 130 and that Young's modulus at room temperature was 13,400 tons/sq. in. The columnar crystals were at right angles to the length of the test piece.

The corresponding value of Young's modulus for a hot-rolled bar of mild steel is of the same order, namely, 13,500 tons/sq. in. Similar test pieces cut from the columnar-grained castings of the 18/8-type stainless steel give low values of Young's modulus. In the mild-steel specimen the presence of columnar grains is evidently not associated with elastic anisotropy since transformation occurs at relatively low temperatures during cooling.

CONCLUSIONS

The columnar grains in highly-alloyed steel castings have a preferred crystallographic orientation such that a [100] direction lies perpendicular to the mould wall from which the crystals have grown. This holds, irrespective of the nature of the primary solidification, *i.e.*, whether face-centred cubic austenite or body-centred cubic ferrite. The orientation is not disturbed by the transformation of primary delta ferrite to austenite, which occurs in certain steels at very high temperatures during cooling. However, the reverse transformation from primary austenite to ferrite, which occurs at lower temperatures, 600° C. and below, in steels of lower-alloy content, including mild steel, appears to eliminate the preferred orientation of the columnar grains. Thus, castings of the plain carbon or low-alloyed steels are not subject to the elastic anisotropy of the outer columnar regions which is a feature of certain cast stainless steels.[2]

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1. F. C. Nix and E. Schmid: *Zeitschrift für Metallkunde*, 1929, vol. 21, pp. 286–292.
2. J. I. Morley: "Symposium on High-Temperature Steels and Alloys for Gas Turbines," pp. 195–204, London, 1951: The Iron and Steel Institute.
3. L. Northcott: *Journal of the Institute of Metals*, 1939, vol. 65, pp. 173–204.

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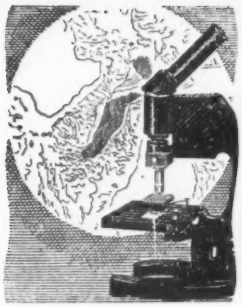
B. I. S. R. A.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION



A Theory of Tube Sinking

By S. Y. Chung, Ph.D., B.Sc.(Eng.), A.M.I.Mech.E., and H. W. Swift, M.A., D.Sc.(Eng.), M.I.Mech.E.

SYNOPSIS

The stresses and strains during tensile sinking of tubes are described. A theory is developed to calculate the sinking load and to predict the thickness and elongation strains that occur during tube sinking in dies of industrial profile. Friction, bending, thickness variation, and strain-hardening are considered, and the effects of ' thickness ' stress distribution on strain development are investigated.

Experiments have been carried out on steel, brass, and copper tubes of 1¾-in. outside diameter and various wall thicknesses. Theoretical and experimental sinking loads, final and intermediate thickness, and elongation strains are comprehensively compared.

It is concluded that the theory can be applied with confidence to industrial tube sinking, to predict sinking loads as well as thickness and elongation strains.

Introduction

HOLLOW-sinking (or tensile-sinking) is a well-known and common process in the manufacture of both seamless and welded tubes. Its main functions are (i) to reduce the tube diameter, (ii) to modify the mechanical properties of the material, (iii) to attain a closer tolerance on the outside diameter, and (iv) to improve the degree of surface finish. Compared with plug drawing, in which a mandrel (or plug) is inserted in the die to govern the final thickness of the drawn tube, the hollow-sinking method generally gives a heavier draft.

Sachs and Baldwin,[1] Swift,[2] Hill,[3] and Chung[4] have developed theoretical accounts of the hollow-sinking of thin-walled tubes in straight-tapered dies. In all these theories it is assumed that the tube wall is so thin in comparison with the diameter that the effects of both plastic bending and the third principal ' thickness ' stress can be neglected. Although reasonable correlation with experiment is found when these theories are applied to very-thin-walled tubes, they cannot be applied to tubes of thicknesses commonly used in industry.

Furthermore, the dies adopted in industry seldom have straight-tapered profiles; they usually have circular profiles consisting of either a single arc or two circular arcs, generally of equal radius. A standard design of industrial die profile is shown in Fig. 1, in which the total virtual conical angle θ_c usually lies between 20° and 40°. With a given draft $(D_0 - D_1)$, the appropriate die profile radius ρ_d can be obtained from the relationship:

$$\rho_d = \frac{(D_0 - D_1)}{8 \sin^2(\frac{1}{2}\theta_c)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The purpose of this paper is to present an analytical treatment by means of which it may be possible to predict the stresses induced and the strains developed (and hence also the sinking loads required) during hollow-sinking of tubes of ordinary thicknesses in dies of industrial profile. Die friction, plastic bending, thickness variation, and strain-hardening are taken into account, and the effects of principal ' thickness ' stress on the development of strains during ' radial ' drawing are considered.

Notation

The following symbols are used:

- B = constant in the empirical representative stress/strain equation
- b_1, b_2, b_3, b_4 = portions of sinking stress due to bending at entry and inflexion point and to unbending at inflexion point and exit, respectively
- D_0, D_1 = diameters of die throat at entry and exit, respectively
- e_1, e_2, e_3 = principal logarithmic strains
- f = portion of sinking stress due to die friction
- g = sinking stress adjustment due to thickness changes
- m = slope of the representative stress/strain curve
- n = dimensionless constant for strain-hardening characteristic of the material
- P = sinking load

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Dr. Chung was formerly at the University of Sheffield. Dr. Swift is Professor of Engineering at the University.

p_1, p_2, p_3
= principal stresses
p = principal sinking stress parallel to the die profile
p_a, p_b, p_c, p_d, p_e
= total sinking stresses at points A, B, C, D, and E, respectively
p_i = principal longitudinal stress during plastic bending when strain-hardening is neglected
p_o = normal pressure on die profile
p° = sinking stress when die friction and thickness changes are neglected
q = representative stress (R.M.S. shear stress)
$= \sqrt{\frac{1}{12}}\sqrt{\Sigma(p_1 - p_2)^2}$
R_a, R_e
= mean radii of tube at entry and exit, respectively
R_b (or R_c)
= mean radius of tube at point of inflexion
r = current mean radius of tube
t = current wall thickness of tube
t_0, t_e
= initial and final wall thicknesses of tube
t_a, t_b, t_c, t_d
= wall thicknesses of tube at points A, B, C, and D, respectively
V = volume of metal
W = strain work due to plastic deformation
Y = yield stress in uni-axial tension
θ_c = total virtual conical angle of die
ψ = representative strain $= \sqrt{\frac{1}{12}}\int\sqrt{\Sigma(de_1 - de_2)^2}$
ϕ = dimensionless constant in the empirical representative stress/strain equation
λ = displacement of the neutral axis from the central layer during plastic bending
μ = coefficient of friction
ρ = radius of curvature
ρ_n = radius of curvature of the neutral axis
ρ_0 = radius of curvature of the central layer.

THE SINKING PROCESS

Figure 2 shows the stresses and strains occurring during sinking. When an element of metal in the original tube enters the die profile at the entry point A, plastic deformation starts by bending, at that point, to the (mean) profile radius ρ_a. This requires a sinking stress p_a $(= b_1)$, but since no back tension exists during the bending operation, no appreciable thickness change will occur,[5] and therefore $t_a = t_0$. As the metal element is drawn in between A and B, the tensile sinking stress increases continuously because of the 'radial' drawing and die friction. The metal thickness also increases, as a result of the predominating hoop compression during the early stage of drawing. At the inflexion point B, C the metal element first unbends and then bends to the reverse curvature under the tensile stress p_b, thus undergoing immediate thinning in two stages from t_b to t_c. To provide the strain work of bending and unbending, the sinking stress is increased by an amount $b_2 + b_3$. Over the lower half of the die profile between C and D, the sinking stress and (generally) the metal thickness again increase continuously to p_d and t_d, respectively, at point D, where final unbending under tensile stress p_d takes place. This unbending operation raises the sinking stress further by an amount b_4, but decreases the metal thickness from t_d to t_e, which is the final thickness of the sunk tube.

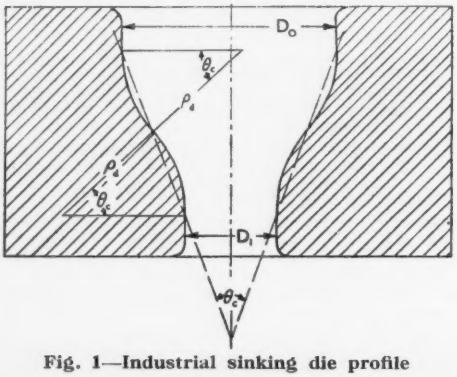

Fig. 1—Industrial sinking die profile

ANALYTICAL TREATMENT

Bending at Entry

When a metal element, of initial thickness t_0, in the undeformed tube reaches the die profile, it is plastically bent to the mean radius of curvature $\rho_a = \rho_d - \frac{1}{2}t_0$. Provided that this bending is instantaneous, the metal element has no freedom to strain in the circumferential direction, and hence the corresponding hoop (or circumferential) strain is zero.

The three principal stresses involved in the bending operation (*see* Fig. 3*a*) are (i) the longitudinal stress p_1, which varies across the wall with the bending strain ; (ii) the circumferential stress p_2 perpendicular to the plane of the paper ; and (iii) the 'thickness' stress p_3, which must vanish at both surfaces but not necessarily in the region of the neutral axis of bending. In industrial tube sinking, where the ratio ρ_d/t_0 is seldom less than 5, the mean numerical value of p_3 does not amount to more than 5% of p_1.[6] If this stress p_3 is neglected, then, in the absence of hoop strain, the Lévy-Lode stress-strain relation requires that $p_2 = \frac{1}{2}p_1$.

A general characteristic relationship between stress and strain in the plastic region may be assumed[7] in the form $q = F(\psi)$, where q (here called the representative stress) is the R.M.S. shear-stress, and ψ (here known as the representative strain) is the corresponding strain analogue. In the plane stress and plane strain system under consideration, ψ can be defined by $\delta\psi = \pm\sqrt{\frac{1}{2}}\delta e_1$ being positive under any plastic strain.

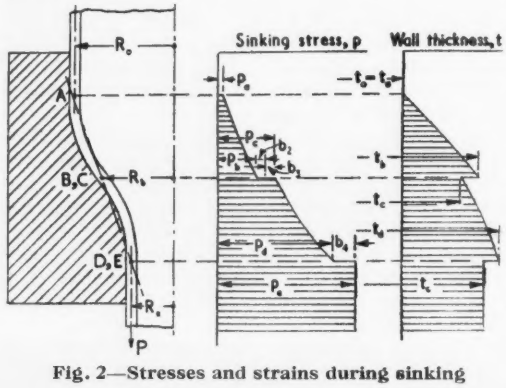

Fig. 2—Stresses and strains during sinking

With the minimum value of ρ_d/t_0 the total increment in ψ during bending will not exceed 0·067. It is reasonable to assume a linear representative stress/strain relationship over this range, so that :

$$q = q_i + m(\psi - \psi_i), \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where the constant m is the slope of the q/ψ curve, and ψ_i is the representative strain corresponding to the condition (q_i) when bending commences. Since $p_1 = 2\sqrt{2}.q$, the longitudinal stress can be written, using the notation given in Fig. 3*b*,

$$p_1 = p_i \pm 2m\log_e\left(\frac{\rho}{\rho_n}\right),$$

where p_i, the initial longitudinal stress, is equivalent to $2\sqrt{2}.q_i$

If bending occurs under a mean tensile stress p_1, the neutral axis NN (Fig. 3*b*) will be displaced from the central fibre CC (radius of curvature ρ_0) by an amount λ, which can be determined by equating the back tension to the difference between the tension and compression due to bending. Neglecting elastic strains :

$$pt = \int_0^{\frac{t}{2}+\lambda} \left[p_i + 2m\log_e\left(1 + \frac{h}{\rho_n}\right)\right] dh - \int_0^{\frac{t}{2}-\lambda} \left[p_i + 2m\log_e\left(1 - \frac{h}{\rho_n}\right)\right] dh,$$

which gives (within about 1% over the useful range) :

$$\lambda = \frac{pt}{2\left(p_i + m\frac{t}{\rho_n}\right)} \quad \ldots\ldots\ldots\ldots (3)$$

(In these equations, t is the metal thickness immediately after bending.) Equation (3) may be solved by successive improvement, using, for the first approximation, $t = t_0$ and $\rho_n = \rho_0$. The thickness strain e_3 due to bending may then be computed as :

$$e_3 = \log_e\left(\frac{t}{t_0}\right) = \log_e\left(\frac{\rho_n}{\rho_n + \lambda}\right).$$

The work δW required to strain any element δV under three-dimensional stress is :

$$\delta W = \delta V.\Sigma(\int p_1 \,.\, de_1).$$

For present purposes, neglecting elastic strains and noting that $e_2 = 0$ and $p_3 = 0$, this expression becomes :

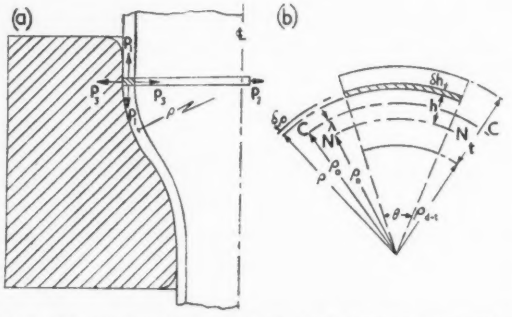

Fig. 3—Plastic bending : (*a*) Principal stresses involved ; (*b*) notation used for analysis

$$\delta W = \delta V \int_0^{e_1} p_1 . de_1,$$

which, when $e_1 = \log_e\left(\frac{\rho}{\rho_n}\right)$, gives the work required to strain an element $\delta V = \rho.\theta.\delta\rho$ (of unit width) of the type shown shaded in Fig. 3*b*. The total work of bending is therefore :

$$W = \theta\int_{\rho_n}^{\rho_d} \rho \int_0^{e_1} p_1 . de_1 \, d\rho - \theta \int_{\rho_{d-t}}^{\rho_n} \rho \int_0^{e_1} p_1 . de_1 \, d\rho.$$

Simplifying, and substituting $\omega = 2\lambda/t$, the expression becomes approximately :

$$W = \frac{t^2\theta}{24}\left[6p_i\left\{1 + \omega^2 + \frac{\omega t}{2\rho_n}\left(1 + \frac{\omega^2}{3}\right)\right\} + 2m\,\frac{t}{\rho_n}\left(1 + 3\omega^2\right)\right] = \frac{t^2\theta}{24} \,.\, Q, \text{ say.}$$

If b is the portion of the sinking stress, at the drawing end of the tube, that is required to provide this amount of work, it can be shown (by differentiating with respect to the metal movement) that :

$$b = \frac{W}{t\rho_0\theta} = \frac{t}{24\rho_0} \,.\, Q \quad \ldots\ldots\ldots\ldots (4)$$

When this procedure is applied to the bending action at point A, where the back tension $p = 0$, it follows from equation (3) that $\lambda = 0$, so that $e_3 = 0$; *i.e.*, no thinning is involved in this bending process. Moreover, in this case $\omega = 0$ and $\rho_n = \rho_0 = \rho_a$, and therefore :

$$b_1 = p_a = \frac{t_a}{12\rho_a}\left(3p_i - m\frac{t_a}{\rho_a}\right) \quad \ldots\ldots\ldots\ldots (5)$$

Initial Sinking Before Contraflexure

Within the region in which $R_a > r > R_b$, the stresses acting on an elementary ring are as shown in Fig. 4*a*. It is assumed that, despite the presence of the shear stress μp_0 operating at the interface, the 'thickness' stress p_3 (normal to the thickness) remains as one of the three principal stresses, the other two of which are the sinking stress p_1 (parallel to the die profile) and the hoop (or circumferential) stress p_2. For simplicity in notation, the suffix for the principal stress p_2 will be suppressed, and the value of p_2 will now not be intermediate between p_1 and p_3 as in normal convention.

Resolving horizontally the forces acting on half of the ring, using the notation of Fig. 4*a* :

$$p_2 t.\delta s - p_0 r \,.\, \delta s \sin\theta(1 - \mu\cot\theta) - d(ptr\cos\theta) = 0 \quad \ldots (6)$$

Resolving vertically the forces acting on the whole ring :

$$p_0 r.\delta s\cos\theta(1 + \mu\tan\theta) - d(ptr\sin\theta) = 0 \quad \ldots\ldots\ldots (7)$$

Eliminating p_0 between equations (6) and (7), and substituting $\delta s = \delta r/\cos\theta$, gives an equation of equilibrium which can be simplified to the form :

$$p_2(1 + \mu\tan\theta) - \frac{d}{dr}(pr) - p.\frac{r}{dr}\cdot\frac{dl}{t} + \mu pr\frac{d\theta}{dr} = 0, \quad \ldots (8)$$

in which $d\theta/dr = 0$ when a straight-tapered sinking die is used.

If shear resilience were again adopted as the criterion for plastic flow, the analytical consequences would be troublesome. However, it can be shown that, within the relevant range of stress values in practical tube sinking ($p > 0 > p_3 > p_2$), the ratio of greatest stress

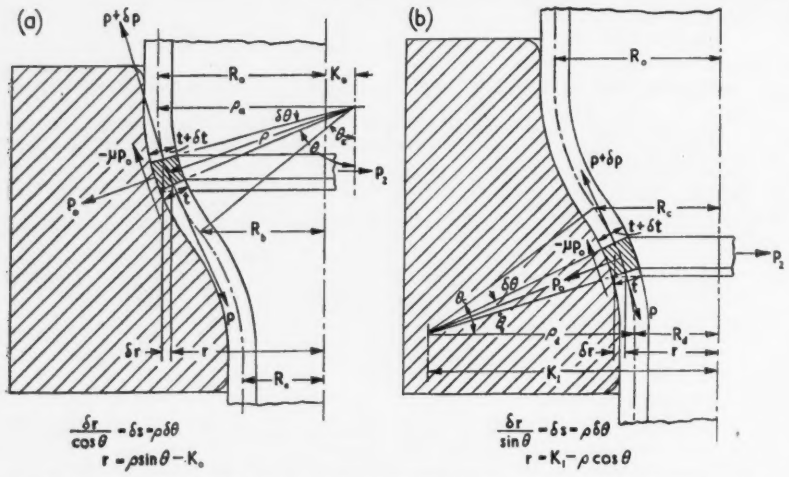

Fig. 4—Stresses acting on an elementary ring: (*a*) between R_0 and R_b; (*b*) between R_c and R_d

difference $(p - p_2)$ to the quantity $q\sqrt{6}$ always lies between 1 and $2/\sqrt{3}$; therefore, adoption of the shear stress criterion in the modified form $(p - p_2) = q\sqrt{7}$ will not give rise to differences of more than 8% from the shear resilience criterion.

Substituting the plastic flow criterion $p - p_2 = q\sqrt{7}$ in equation (8), and using the geometrical relation $dr/d\theta = \rho\cos\theta$, the equilibrium equation may be written:

$$dp = -q\sqrt{7}.\frac{dr}{r} - \mu\left[\left(q\sqrt{7} - p\right)\frac{\rho}{r}\sin\theta - p\right]d\theta - p\frac{dt}{t} \quad \ldots\ldots(9)$$

In this equation the effect of changes in thickness is embodied in the final term, which in practice does not exceed 5% of the resultant sinking stress. Moreover, the small transverse stress p_3 has little effect on the value of the sinking stress p. According to the Lévy-Lode hypothesis, the increment of thickness may therefore be written:

$$\frac{dt}{t} = \left[\frac{p + p_2}{p - 2p_2}\right]\frac{dr}{r} = \left[\frac{2p - q\sqrt{7}}{p - 2q\sqrt{7}}\right]\frac{dr}{r}.$$

The solution of equation (9) with this substitution for dt/t is not simple, but a good first approximation to the sinking stress p, differing from the true value by about 2%, is given by:

$$p = p^\circ + f + g \quad \ldots\ldots(10)$$

where $$p^\circ = p_a - \sqrt{7}\int_{R_a}^{r} q.\frac{dr}{r} \quad \ldots\ldots(11)$$

is the sinking stress neglecting die friction and thickness changes;

$$f = -\int_{\frac{\pi}{2}}^{\theta}\mu\left[\left(q\sqrt{7} - p^\circ\right)\frac{\rho}{r}\sin\theta - p^\circ\right]d\theta \quad \ldots\ldots(12)$$

is the stress increment due to die friction; and

$$g = \int_{R_a}^{r}\left(p^\circ + f\right)\left(2 + \frac{3q\sqrt{7}}{p^\circ + f - 2q\sqrt{7}}\right)\frac{dr}{r} \quad \ldots\ldots(13)$$

is the adjustment due to thickness changes. A second approximation, obtained by substituting the first approximation of p for p° in equations (11) and (12) and for $(p^\circ + f)$ in equation (13), is considered to be accurate to a fraction of a percent. In the upper limits of these integrands, the values of r lie between R_a and R_b and those of θ between $\frac{1}{2}\pi$ and θ_c.

The value of p° depends upon the representative stress-strain relationship for the material. This can conveniently be expressed in the general form $q = B(\psi + \phi)^n$, where B, ϕ, and n are empirical constants which can be determined from a simple tensile test. Under practical conditions of drawing from R_a to R_b, the representative strain of a metal element is within about 2% of the value $\sqrt{\frac{2}{3}}.\log_e(R_a/r)$, so that equation (11) may be written:

$$p^\circ = p_a + \sqrt{\frac{8}{3}}\frac{B\sqrt{7}}{(n+1)}\left[\left(\sqrt{\frac{2}{3}}\log_e\frac{R_a}{r} + \psi_a + \phi\right)^{n+1} - (\psi_a + \phi)^{n+1}\right], \quad \ldots\ldots(14)$$

where ψ_a is the mean representative strain imparted to the element during the initial plastic bending at A, and is approximately $\frac{1}{\sqrt{2}}\log\left(1 + \frac{t_a}{4\rho_e}\right)$.

The value of the die pressure p_0 can be calculated from equation (7), which, substituting $\delta s\cos\theta = \delta r$, dp from equation (9), and simplifying, can be written:

$$p_0 = \frac{t}{\rho}.p - \frac{t}{r}\sin\theta\,(q\sqrt{7} - p) = x.p - y(q\sqrt{7} - p), \text{ say} \quad \ldots\ldots(15)$$

With a straight-tapered die, $x = 0$.

The value obtained for the thickness strain dt/t in terms of the hoop strain dr/r depends on the assumption made regarding the distribution of 'thickness' stress across the thickness of the tube wall. If it is assumed that p_3 varies linearly across the section from p_0 to 0, having a mean value $\frac{1}{2}p_0$, then the Lévy-Lode stress and incremental strain relationship, combined with the condition $p - p_2 = q\sqrt{7}$, leads to the expression:

$$\log_e\frac{t}{t_a} = \int_{t_a}^{t}\frac{dt}{t} = 2\int_{R_a}^{r}\frac{p\,(x + y - 2) + q\sqrt{7}\,(1 - y)}{p\,(2 - x - y) - q\sqrt{7}\,(4 - y)}.\frac{dr}{r} \quad \ldots(16)$$

for the thickness strain increment.

Flexure at the Point of Inflexion

At the point of inflexion B, C each metal element first unbends and then bends in the reverse sense, *i.e.*, its curvature is reversed.

Unbending is in effect a reverse plastic bending, and may be treated as such. Thus, neglecting the Bauschinger effect, the displacement λ_b of the neutral axis from the central layer can be found from equation (3) by substituting :

$$p = p_b \text{ and } t = t_b$$

$$p_i = 2\sqrt{2}\left[\sqrt{\tfrac{3}{8}}\log_e\left(\frac{R_a}{R_b}\right) + \psi_a + \phi\right]^n$$

$$m = nB\left[\sqrt{\tfrac{3}{8}}\log_e\left(\frac{R_a}{R_b}\right) + \psi_a + \phi\right]^{n-1}$$

The corresponding thickness strain is $\log_e\left(\frac{t}{t_b}\right) = \log_e\left(1 - \frac{\lambda_b}{\rho_b}\right)$; the mean representative strain increment $\Delta\psi_b$ is approximately $\frac{1}{\sqrt{2}}\log_e\left(1 + \frac{t}{4\rho_b}\right)$; and the differential sinking stress b_2 is given by equation (4), using $\omega = 2\lambda_b/t$ and the values given above.

The reverse bending at C involves a displacement λ_c and a differential sinking stress b_3, which are found from equations (3) and (4) by substituting :

$$p = p_b + b_2 \text{ and } t = t_c$$

$$p_i = 2\sqrt{2}\left[\sqrt{\tfrac{3}{8}}\log_e\left(\frac{R_a}{R_b}\right) + \psi_a + \Delta\psi_b + \phi\right]^n$$

$$m = nB\left[\sqrt{\tfrac{3}{8}}\log_e\left(\frac{R_a}{R_b}\right) + \psi_a - \Delta\psi_b + \phi\right]^{n-1}$$

The corresponding thickness strain is $\log_e\left(\frac{t_c}{t}\right) = \log_e\left(1 - \frac{\lambda_c}{\rho_c}\right)$, and the mean representative strain increment $\Delta\psi_c$ is approximately $\frac{1}{\sqrt{2}}\log_e\left(1 + \frac{t_c}{4\rho_c}\right)$.

Sinking After Inflexion

The stress and strain changes between C and D (Fig. 2) can be investigated in a similar way to those between A and B. To a first approximation between these limits, using the notation of Fig. 4*b*, the sinking stress p is given by :

$$p = p^\circ + f + g,$$

where :

$$p^\circ = p_c - \sqrt{7}\int_{R_c}^{r} q\frac{dr}{r}$$

$$f = -\int_{\theta_c}^{\theta}\mu\left[\left(q\sqrt{7} - p^\circ\right)\frac{\rho}{r}\cos\theta + p^\circ\right]d\theta$$

$$g = \int_{R_c}^{r}(p^\circ + f)\left(2 + \frac{3q\sqrt{7}}{p^\circ + f - 2q\sqrt{7}}\right)\frac{dr}{r}$$

In the upper limits of the integrands, θ lies between θ_c and 0 and r lies between R_c and R_d.

Similarly, the die pressure in this region is :

$$p_0 = -\frac{t}{\rho}p - \frac{t}{r}\cos\theta(q\sqrt{7} - p)$$
$$= -x.p - z(q\sqrt{7} - p), \text{ say, } \ldots\ldots\ldots(17)$$

and if p_3 has a mean value of $\frac{1}{2}p_0$, the thickness strain increment is :

$$\log_e\frac{t}{t_c} = 2\int_{R_c}^{r}\left[\frac{p(z-x-2) + q\sqrt{7}(1-z)}{p(2+x-z) - q\sqrt{7}(4-z)}\right]\frac{dr}{r} \ldots\ldots(18)$$

The sinking stress p_d and metal thickness t_d at the point D are obtained by writing $r = R_d$ in the above equations.

Flexure in Die Throat

Before the metal element finally emerges from the die to form part of the drawn tube, it has to be unbent at the exit point D, E under a tensile stress p_d (*see* Fig. 2). This operation imparts an additional differential sinking stress b_4 to the sinking end of the tube, and causes a further immediate thickness strain $\log_e\left(\frac{t_e}{t_d}\right) = \log_e\left(1 - \frac{\lambda_d}{\rho_d}\right)$. The values of λ_d and b_4 can be determined from equations (3) and (4) by inserting the appropriate values of p, t, p_i, ω, and m.

Overall Sinking Data

Having followed the successive stages of the stress and strain increments of a representative element throughout the sinking process, it is a simple matter to assemble the data to cover the operation as a whole.

The final sinking stress is $p_e = p_d + b_4$, the resultant thickness strain $\log_e(t_e/t_0)$ is the sum of terms of the type $\log_e(t_b/t_a)$, and the theoretical sinking load is given by : $P = 2\pi R_e t_e p_e$ ..... (19)

For the sinking operation to be practicable, the sinking load P must not be greater than the tensile strength of the nozzle or the tagged portion. Also, the final sinking stress p_e should not exceed $q_e\sqrt{6}$ (where q_e refers to the representative stress of the sunk tube), otherwise the sunk tube will yield, causing the final outside diameter of the drawn tube to be smaller than the throat diameter of the die.

CORRELATION OF THEORY AND EXPERIMENT

To check the validity of the foregoing analysis under practical conditions, it has been applied to the sinking from $1\frac{3}{4}$ in. to $1\frac{1}{4}$ in. diameter of certain steel, brass, and copper tubes, of different wall thicknesses, through a die (of the form shown in Fig. 1) which was constructed for the purpose. For comparison, measurements have been made of the actual sinking loads, diameter, elongation, and thickness changes that occur when such tubes are sunk at a slow speed in a testing machine.

Experimental Procedure

The experimental sinking die has a total virtual conical angle of 26° and a profile radius of 1·226 in.,

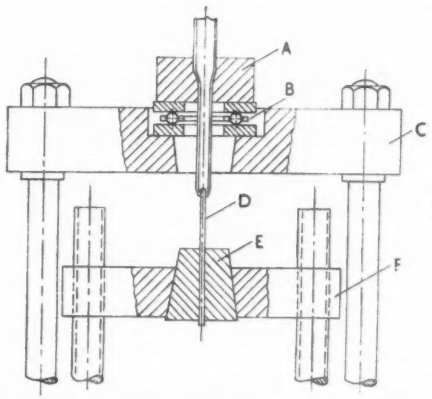

Fig. 5—Arrangement for experimental tube-sinking

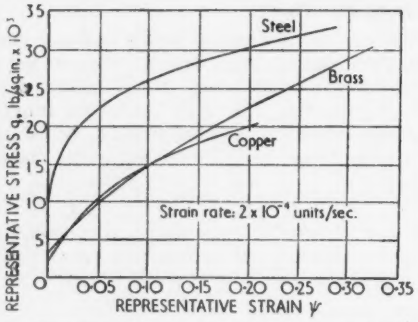
Steel
Brass
Copper
Strain rate: 2 x 10⁻⁴ units/sec.
REPRESENTATIVE STRESS q, lb/sq.in. x 10³
REPRESENTATIVE STRAIN ψ
0 0·05 0·10 0·15 0·20 0·25 0·30 0·35
0 5 10 15 20 25 30 35

Fig. 6—Representative stress/strain relationship of materials

and the values of D_0 and D_1 (Fig. 1) are $1\frac{3}{4}$ and $1\frac{1}{4}$ in., respectively. The die was prepared and hard-chromium-plated according to the usual industrial practice, giving an average surface hardness of about 500 D.P.H.

The sinking experiments were carried out in a Riehle multi-lever testing machine. The die *A* was mounted above a plain ball thrust-bearing *B*, which was inserted in a recess in the upper cross-member *C* of the machine (*see* Fig. 5). A $\frac{5}{8}$-in. dia. alloy steel drawing pin *D* was gripped by two wedge-shaped clamps *E* in the moving cross-head *F* of the machine. The sinking speed was about 1 in./min., and the lubricant used was graphite in tallow in the proportion of 1 : 3 by weight.

Although the sinking load was not exactly constant, it was found that the load fluctuation did not exceed $\pm$ 2% of the mean value.

The final elongation strains were measured on a 2-in. gauge length, in four perpendicular radial planes, by means of a travelling microscope graduated to 10^{-4} in. Measurements of the wall thickness were made by means of a simple dial-gauge jig graduated to 10^{-4} in. and capable of consistent registration to half a division. Four (and in some cases eight) measurements were taken round the circumference of the tube cross-section, to obtain a true value of the mean thickness.

For convenience in the measurement of intermediate strains, a portion of the tube, before sinking, was scribed on the outer surface with circumferential lines spaced at 0·1-in. intervals along the axis. This scribed portion was so chosen that, at the end of the experiment, part of it was within the die, part was undrawn, and part was fully drawn.

The profile of the scribed portion was measured in a universal milling machine, by means of a dial-gauge mounted on the lever arm, the tube being clamped on the dividing head. Measurements were made on the scribed lines in four radial planes, and the original and final diameters were checked by micrometer. Intermediate wall thicknesses were measured half-way between scribed lines on the four segments into which the tube was sawn for convenience of measurement.

No attempt was made to measure the intermediate elongation strains, which can be more accurately deduced from the measured hoop and thickness strains by the condition of volumetric constancy.

Properties and Particulars of Tubes

Mild-steel, brass, and copper tubes of $1\frac{3}{4}$-in. outside diameter and of different wall thicknesses were used ; details are as follows :

Material	Outside Diameter, in.	Wall Thickness, in.	D.P.H. (10 kg.)
0·1–0·13% C steel	1·7405	0·1305	121
,,	1·7405	0·1052	122
,,	1·7480	0·0794	109
,,	1·7475	0·0635	110
,,	1·7500	0·0400	116
70/30 Brass	1·7450	0·0647	56
Copper	1·7550	0·0608	48

The steel tubes were supplied already nozzled and in the fully annealed state. The brass and copper tubes, after nozzling, were annealed for 10 min. at 750° and 650° C., respectively, and were de-scaled by quenching in cold water at the annealing temperature.

The representative stress/strain relationships of the tube materials (q/ψ curves, derived from the ordinary uni-axial tensile tests[7]) are plotted in Fig. 6, in which

$$q = \frac{1}{\sqrt{6}}Y \text{ and } \psi = \sqrt{\tfrac{2}{3}}\log_e\left(\frac{l}{l_0}\right).$$

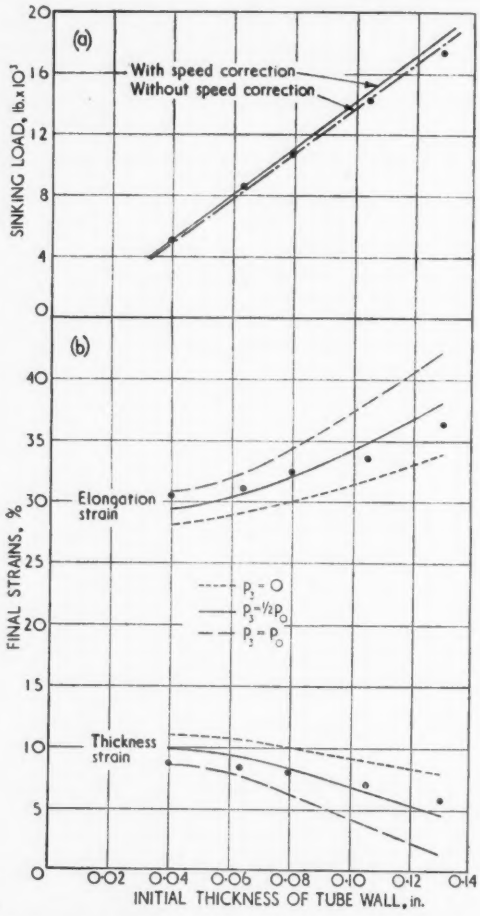

Fig. 7—Comparison of theoretical curves and experimental results for steel tubes of varying wall thickness. The experimental results are shown as solid points. (*a*) Sinking loads ; (*b*) final strains

Comparison of Results

Mild Steel Tubes of Various Wall Thicknesses—The experimental values of sinking load are plotted in Fig. 7*a*, together with curves showing the corresponding theoretical loads. The solid curve takes into account the strain rate correction, amounting to about + 3%, which is made to allow for the difference of strain rates between uni-axial tension testing ($\dot{\psi} \simeq 2 \times 10^{-4}$ units/sec.) and tensile tube sinking ($\dot{\psi} \simeq 4 \times 10^{-3}$ units/sec.), and has been estimated according to Manjoine.[8]

The relative significance of the various constituents of the theoretical sinking stress, for two different wall thicknesses, is shown in Table I. The effect of thickness variation is small, and if it is neglected the sinking stress is overestimated by about 4%. On the other hand, the effects of friction and bending are substantial, being 10–20% in both cases. In these theoretical calculations, the coefficient of friction was assumed, as a result of earlier work,[5] to be 0·06.

It is not possible to make a full comparison of the results of the present analysis with those of earlier theories, which have not only neglected the effects of bending but have assumed a simple conical die. However, the sinking stress due to bending (Table I)

Table I

CONSTITUENTS OF TOTAL SINKING STRESS

Constituent	Wall Thickness 0·0635 in.		Wall Thickness 0·1305 in.	
	lb/sq. in.	%	lb./sq. in.	%
Pure radial deformation	24,800	75·6	27,320	68·2
Bending and unbending	3920	11·9	8280	20·7
Surface friction	5530	16·8	5970	15·0
Thickness variation	−1400	−4·3	−1560	−3·9
Total	32,850	100	39,990	100

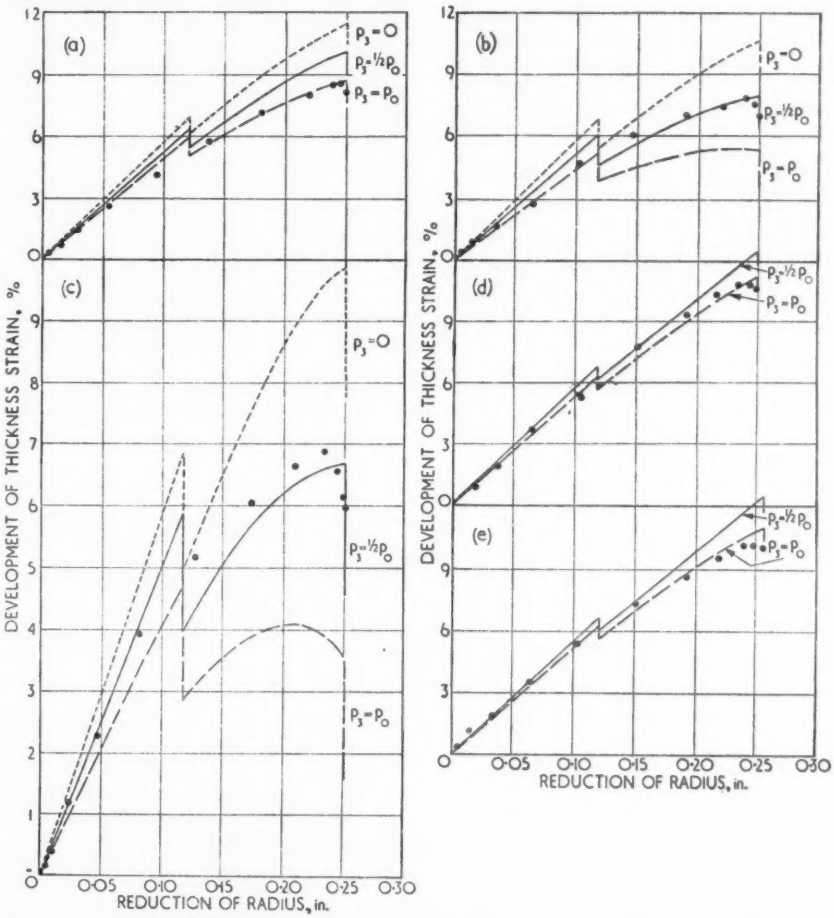

Fig. 8—Theoretical and experimental intermediate strains during sinking of tubes of varying thickness. The experimental results are shown as solid points. (*a*) 0·0635-in. steel tube ; (*b*) 0·1052-in. steel tube ; (*c*) 0·1305-in. steel tube ; (*d*) 0·0647-in. brass tube ; (*e*) 0·0608-in. copper tube

Table II

COMPARISON OF RESULTS

Property	Method	Material		
		Steel	Brass	Copper
Sinking loads, lb.	Theoretical	8700	5180	4550
	Experimental	8560	5060	4130
Elongation strains, %	Theoretical	30·7	27·9	28·3
	Experimental	31·1	28·1	29·7
Thickness strains, %	Theoretical	9·1	11·5	11·7
	Experimental: (i) Direct measurement (e_3)	8·2	10·7	10·0
	(ii) Derived from e_1 and e_3	8·5	11·0	10·1

is about 12% of the total with the thinner-walled tubes and more than 20% with the thicker-walled tubes, and these values represent the errors of earlier theories from this source alone.

The final thickness and elongation strains are plotted in Fig. 7*b*. The solid curves represent the results calculated on the assumption that the mean principal 'thickness' stress during radial deformation is half the die pressure at the interface (*i.e.*, $p_3 = \frac{1}{2}p_0$), whereas the dotted and dashed curves represent the extreme hypotheses $p_3 = 0$ and $p_3 = p_0$, respectively. With thin-walled tubes the die pressure p_0 is apparently transmitted through most of the thickness, whereas with thick-walled tubes it seems to be effective through only a small fraction of the thickness.

This effect is further illustrated in Figs. 8*a–c*, in which measured intermediate thickness strains are superimposed on curves showing the changes predicted by theory based on the three assumptions: $p_3 = 0$, $p_3 = \frac{1}{2}p_0$, and $p_3 = p_0$. On the whole, the assumption $p_3 = \frac{1}{2}p_0$ appears to be justified.

It is found theoretically that the difference between the strain rates during uni-axial tension testing and tensile tube-sinking has no appreciable effect on the strains. This fact has already been observed experimentally by Briggs and Swift,[9] over a range of (representative) straining rates from 6×10^{-2} to 2 units per sec., approximately.

Tubes of Different Metals—Mild-steel, brass, and copper tubes of approximately 0·06-in. wall thickness were investigated. A comparison of theoretical and experimental sinking loads is given in Table II; the theoretical results were calculated on the basis of coefficients of friction of 0·06 for steel and 0·03 for both brass and copper.[5] When the rate of deformation was taken into account, the speed correction factors were found to be approximately 1·03 for both the non-ferrous metals[10] and the steel.[8]

Theoretical and experimental final elongation strains and thickness strains are also shown in Table II. The experimental thickness strains were obtained by (i) direct measurement, and (ii) derivation from measured values of hoop and elongation strains.

Experimental values of the intermediate thickness strains for steel, brass, and copper are shown superimposed on the corresponding theoretical curves in Figs. 8*a*, *d*, and *e*, respectively. The solid curves indicate the predicted thickness strain development when the mean 'thickness' stress p_3 is assumed to be half the value of the die pressure p_0, whereas the dashed curves represent the development if p_0 were effective over the entire thickness.

CONCLUSIONS

For all the tubes, the correlation between theoretical values of sinking loads and the experimental results is good. The principal thickness and elongation strains (particularly the former) are sensitive to the principal 'thickness' stress, especially when the wall-thickness/tube-diameter ratio is comparatively large. Of the three assumptions of the distribution of the principal 'thickness' stress, the assumption of linear distribution from $p_3 = p_0$ at the interface to $p_3 = 0$ at the inner surface is the most justifiable, except for very thin-walled tubes.

Stress/strain properties of the different materials have a marked effect on the sinking loads but not on the strains, which differ only slightly between the three materials investigated.

It is believed that, within the normal industrial range, the theory can confidently be used to predict sinking loads for the assessment of draw-bench ratings, and to estimate wall thicknesses and length increments for sunk tubes.

Acknowledgments

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An Experimental Furnace for the Investigation of Open-Hearth-Furnace Combustion Problems

PART V—EXPERIMENTS WITH THE VENTURI PORT AND MODIFICATIONS THEREOF

By J. F. Allen, B.Sc.

SYNOPSIS

The effect on heat transfer of the position of the gas-port nose and the steepness of the ramp roof in ports of the Venturi type were examined. Improved results were obtained by moving the gas port back and by steepening the roof ramp.

High furnace pressure and theoretical air are beneficial to heat transfer, although in some cases a moderate excess of air cools the roof and so permits a higher rate of dri ving and an increased heat transfer to the hearth.

PARTS I–IV of this series of papers described work on a model furnace made available to B.I.S.R.A. through the courtesy of the Shelton Iron, Steel, and Coal Co., Ltd. Part I[1] described the experimental plant and discussed the conditions of similarity with full-scale practice that must be observed. Part II[2] described experiments with a conventional type of port, Part III[3] experiments with Maerz and modified Maerz ports, and Part IV[4] the influence of design and operation factors on roof temperatures.

The results of these experiments may be summarized as follows :

(1) For any design of furnace so far investigated, a high furnace pressure and theoretical air are conducive to increased heat transfer to the hearth, for a given heat input. In some cases maximum heat transfer to the hearth, without exceeding a given roof temperature, is possible by using some excess air, at the cost of an increased fuel consumption

(2) In designs where the turbulent mixing of gas and air takes place mainly by diffusion, a small gas port offers advantages over a large gas port provided that the normal air port, giving a low-velocity air stream, is used

(3) Designs in which turbulent mixing is assisted by direct impingement of the gas and air streams give satisfactorily high heat transfer to the hearth and in such designs the size of the gas port is of less importance

(4) Some experimental designs, in which mixing takes place by direct impingement of the gas and air stream could not yet be utilized in production open-hearth furnaces. However, a simple version of such a design, with a single air uptake at each end in place

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Mr. Allen is on the staff of the Steelmaking Division of the Association.

Table I—DIMENSIONS OF THE PORTS

Design No.	Gas Port Details			Air Uptake Details					Ramp Angle, degrees	Throat Area, sq. ft.
	Area, sq. in.	Length, in.	Angle, degrees	No. of Uptakes	Length, in.	Width, in.	Area, sq. in.	Total Area sq. in.		
9a	26	25	10	2	13	8½	110½	221	35	3·53
9b	9	25	10	2	13	8½	110½	221	35	3·53
10a	26	21	10	2	13	8½	110½	221	35	3·53
10b	9	21	10	2	13	8½	110½	221	35	3·53
11a	26	17	10	2	13	8½	110½	221	35	3·53
11b	9	17	10	2	13	8½	110½	221	35	3·53
12a	26	12	10	2	13	8½	110½	221	35	2·0
12b	9	12	10	2	13	8½	110½	221	35	2·0
13a	26	25	10	2	13	8½	110½	221	60	2·0
13b	9	25	10	2	13	8½	110½	221	60	2·0
14a	26	12	10	2	13	8½	110½	221	60	2·0
14b	9	12	10	2	13	8½	110½	221	60	2·0
15a	26	8	10	1	13	7¼	94¼	94¼	60	2·0
15b	9	8	10	1	13	7¼	94¼	94¼	60	2·0
16a	26	8	10	1	7	7	49	49	60	2·0
16b	9	8	10	1	7	7	49	49	60	2·0

of the customary two, lends itself to immediate use in many existing furnaces, particularly those fired by oil

(5) Adequate instrumentation is necessary for any design of furnace for the correct setting of operational variables to be assessed, particularly with the more efficient designs.

EXPERIMENTAL PROCEDURE

The present series of experiments was conducted to ascertain the effect of the position of the gas-port nose, and the steepness of the ramp roof in ports of the Venturi type. The basic design used was similar to that used for the work described in Part II, but more care was taken to reproduce the Venturi lines.

Figure 1 shows the sectional elevation of the furnace in which, as given in Part I, the heat usefully transferred to the hearth for a given heat input is measured by a water calorimeter. It also shows the different port ends 9–16 used in this series of experiments. Table I gives the dimensions of the various ports.

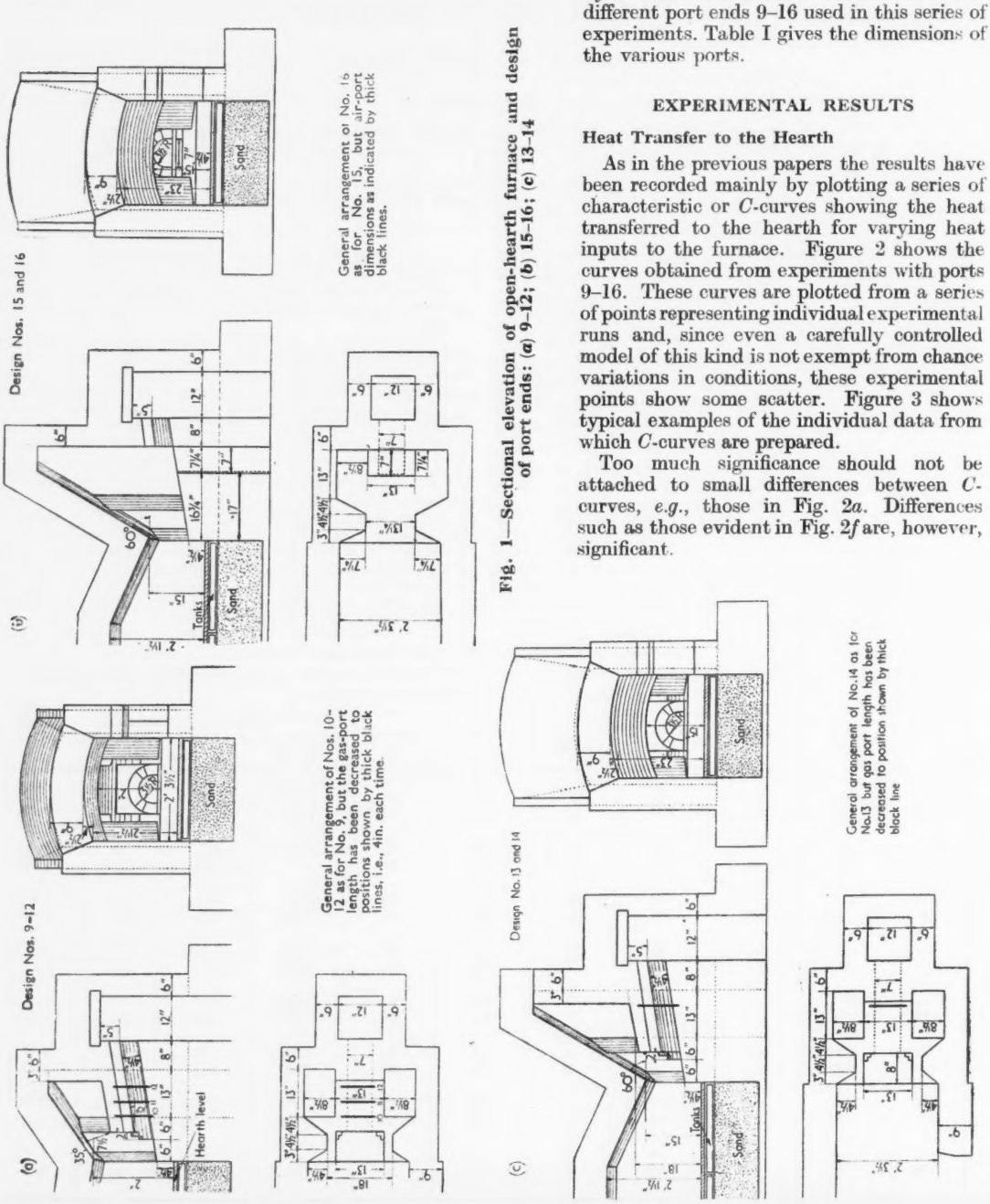
Design Nos. 15 and 16
General arrangement of No. 16 as for No. 15, but air-port dimensions as indicated by thick black lines.
Sand
Tanks
(b)
Design Nos. 9–12
General arrangement of Nos. 10–12 as for No. 9, but the gas-port length has been decreased to positions shown by thick black lines, i.e., 4in. each time.
Hearth level
(a)
Design No. 13 and 14
General arrangement of No. 14 as for No. 13 but gas port length has been decreased to position shown by thick black line
(c)

Fig. 1—Sectional elevation of open-hearth furnace and design of port ends: (*a*) 9–12; (*b*) 15–16; (*c*) 13–14

EXPERIMENTAL RESULTS

Heat Transfer to the Hearth

As in the previous papers the results have been recorded mainly by plotting a series of characteristic or *C*-curves showing the heat transferred to the hearth for varying heat inputs to the furnace. Figure 2 shows the curves obtained from experiments with ports 9–16. These curves are plotted from a series of points representing individual experimental runs and, since even a carefully controlled model of this kind is not exempt from chance variations in conditions, these experimental points show some scatter. Figure 3 shows typical examples of the individual data from which *C*-curves are prepared.

Too much significance should not be attached to small differences between *C*-curves, *e.g.*, those in Fig. 2*a*. Differences such as those evident in Fig. 2*f* are, however, significant.

Effect of Air/Gas Ratio

In the earlier work it was shown that, in general, the use of theoretical air gave higher thermal efficiencies than were obtained with varying proportions of excess air. This would be expected from theory, yet in practice many of the fastest working furnaces operate with a moderate quantity of excess air. In Part IV it was shown that whilst the best heat transfer to the hearth for a given heat input was attained with theoretical, or slightly deficient air, the best heat transfer to the hearth not exceeding a given roof temperature (which is of more practical importance when high outputs are demanded) might be attained under certain conditions with a moderate amount of excess air. This result was confirmed in the present series of experiments (*see* p. 43).

That an excess of relatively cool air can move along the underside of the roof and protect it from overheating is supported by the flow-pattern work of Chesters and his colleagues.[5] It is, however, necessary to differentiate between air provided in excess of that required for theoretical combustion of the fuel, *i.e.*, excess air, and that quantity absorbed by chemical oxidation of the materials in the bath for which some allowance should be made.

However, considering fuel efficiency alone, the thermal efficiency and the proportion of excess air used for combustion are in agreement with the theoretical values and with those given by simpler combustion appliances. This has been so evident in all the earlier work that the latest series of experiments was carried out with theoretical and with 55% excess air only (so as to show up any possible anomaly in the excess air picture without carrying out experiments with a fuller range of air/gas ratios). Exceptions are to be found with port 13 (Fig. 2*j*) with a large gas port, where excess air leads to little loss of efficiency, and with port 14 (Fig. 2*l*) with a large gas port with a pressure of 0·02 in. W.G. and high fuel rates, where excess air tends to enhance the efficiency of the port. These exceptions serve to illustrate the relationship which exists between excess air and port design, *i.e.*, the less efficient designs require excess air to assist in mixing the fuel and air streams.

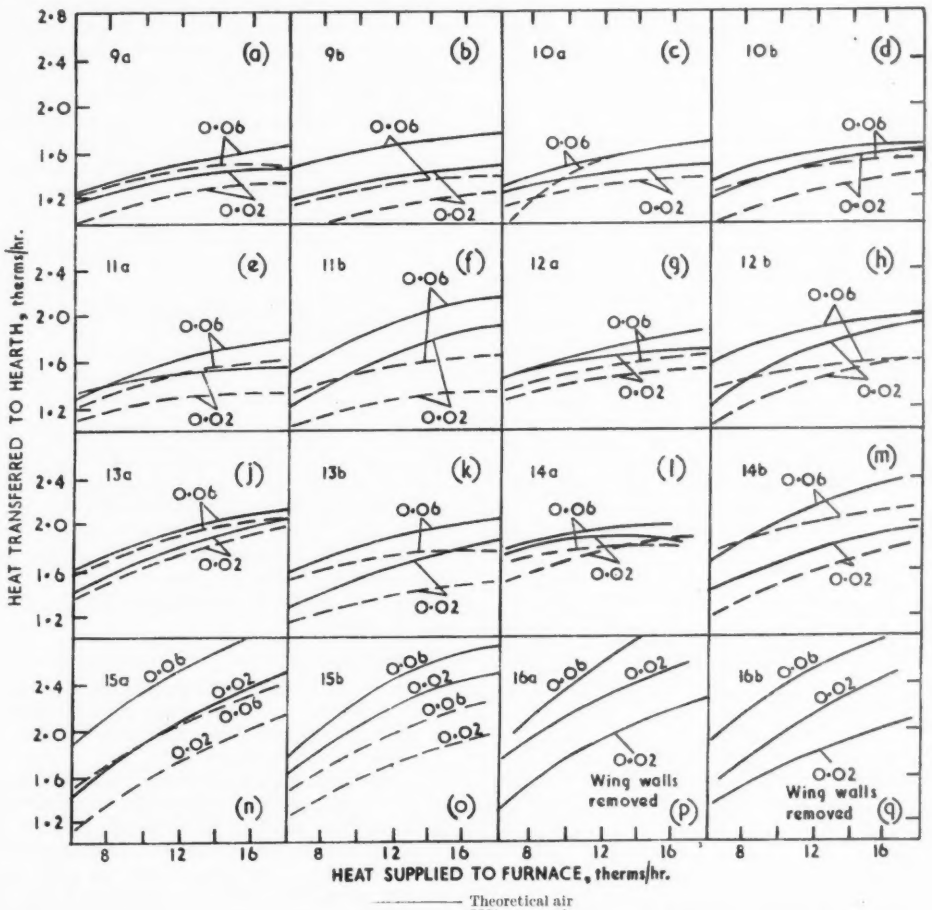

Fig. 2—Heat-transfer curves for modified Venturi ports and certain special designs. The figures in the top left-hand corners refer to port design numbers and indicate total area of the port (*a* = 26 sq. in., *b* = 9 sq. in.). Figures on the curves denote roof pressure in W.G.

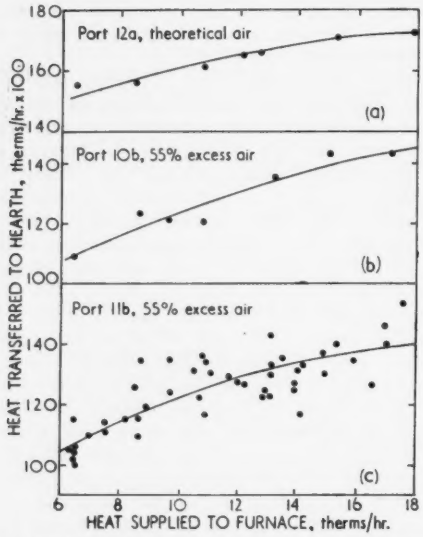

Fig. 3—Typical diagrams from which the *C*-curves in Fig. 2 were prepared, showing individual experimental points: (*a*) and (*b*) Normal satisfactory working; (*c*) unsatisfactory conditions—the furnace needs 'top repair,' gas and water supplies unsteady

Effect of Furnace Pressure

As in the previous experiments (Parts II–IV) increase in furnace pressure (*i.e.*, pressure in the working chamber, not that in the flues or uptakes) resulted in an improvement in the heat transfer to the hearth (*see* Fig. 2). This effect is more apparent if furnace pressure is plotted as the independent variable, as in Fig. 4, which gives the results of a few separate experiments carried out with certain port designs in which the heat input was kept constant and the furnace pressure was varied between $\pm 0{\cdot}06$ in. W.G.

These results are very similar to those recorded in earlier work[3]: the same unexpected phenomenon is observed—the thermal efficiency continues to rise with furnace pressure up to the limits of the experiment. If it is assumed that the main cause of the improvement with rising furnace pressure is the resulting diminution of air infiltration, one would expect a rise of efficiency with pressure up to the value corresponding to zero pressure at the bottom of the doors when all infiltration should be stopped. In the model furnace this value of furnace pressure is about $+ 0{\cdot}025$ in. to $+ 0{\cdot}03$ in.W.G., corresponding to $+ 0{\cdot}08$ to $+ 0{\cdot}10$ in. W.G. in a production furnace. However, efficiency continues to increase at higher pressures and there is considerable 'sting' round the doors, although all infiltration should have stopped.

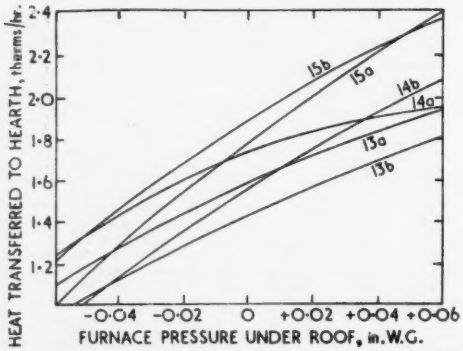

Fig. 4—Effect of furnace pressure on heat transfer to hearth for various port designs. Heat input to furnace 10·8 therms/hr.; theoretical air

In Part III it was pointed out that the suction effect of a fast-moving fuel jet will induce air even if the calculated static pressure is sufficient to exclude all air infiltration. A pressure in excess of the theoretical value calculated on a 'static' basis is therefore necessary to counter this. An additional explanation may lie in the inevitable irregularities in the controlled pressure caused by wind passing over the stack and by other aerodynamic instabilities in the system. Thus, if the controlled pressure is $+ 0{\cdot}03$ in. W.G., giving zero or slightly positive pressure at the sill level in the model, the actual pressure record will appear as shown in Fig. 5.

The shaded areas represent periods during which infiltration will still take place, indicating that a mean pressure much higher than $+ 0{\cdot}03$ in. W.G. would be necessary to stop *all* infiltration. In general, the less efficient ports show a smaller rise of efficiency with furnace pressure than the more efficient ports. There is visual evidence that, with the less efficient ports, flame 'sting' at high pressures contains a high proportion of unburnt gas; with efficient ports the sting, which is either air or combusted gas, is less visible. In other words, the flame sting at high

Fig. 5—Pressure record showing periods during which infiltration will occur

pressures causes a greater loss of heat units with inefficient ports than with efficient ports. It is, however, seldom practicable to operate furnaces with appreciable positive pressure at sill level, because of the uncomfortable conditions and refractory damage resulting from excessive flame 'sting.' It is therefore concluded, as in the previous work, that in practice the furnace pressure should be as high as these limitations permit.

Effect of Gas-Port Size

The effect of gas-port size has been studied for a given gas flow, *i.e.*, the pressure behind a smaller port is increased to the value necessary to give the same gas flow as with a larger port.

In the two types of port previously studied,[2, 3] the effect of gas-port size varied. In the 'conventional' ports studied in Part II, a small gas port generally gave the best results, whilst the Maerz ports and other special designs studied in Part III gave conflicting results, no marked effect of port size being observed. The explanation of these observations is that in all open-hearth flames, mixing the air is caused by turbulent diffusion. This is assisted by the high velocity

and high surface/volume ratio of a jet issuing from a small port. If mixing is substantially assisted by other features of port design, such as the right-angle impingement of the gas and air streams encountered in ports such as the single-uptake variation of the Maerz, gas-port size becomes less important.

The effect of port size is included in the graphs shown in Fig. 2. In some port configurations, and under certain operating conditions, the small port gave better results ; under other conditions the reverse applied. The results are also presented in Table II, in which *S* denotes the best results obtained with a small (9 sq. in.) port and *L* the best results with a large (26 sq. in.) port. Where the indication is given in parenthesis the difference is small and of doubtful significance. As the mixing becomes more assisted by jet impingement, the large gas port tends to become superior.

Ports 9–12 are all variations of the conventional Venturi port with a 35° air ramp, the gas-port nose being moved in stages from a position right forward (port 9) to a position right back in the end wall (port 12). With theoretical air the small port gives better results ; this is, however, less marked when the gas-port nose is in either its extreme forward or extreme back position. With excess air, the influence of port size is much less marked, but is slightly in favour of the large gas port. This is in agreement with earlier observations[2] (p. 411) with a similar port (No. 2). In ports 13 and 14, with a 60° ramp, and with port 15 (a single air uptake under a steeply ramped roof) the effect of port size is either indefinite or slightly in favour of a large port. The most reasonable explanation of this behaviour is that in some ports, size (governing gas velocity) is a major factor in mixing, whilst in others, the other features of design, *e.g.*, angle of impingement of air and gas, obscure or override the effect of gas velocity. A large excess of air assists mixing, at the expense of overall efficiency.

With many port designs of the type now common in open-hearth furnaces, improved results are to be expected with a small gas port, but with the newer port designs, which have a high inherent mixing

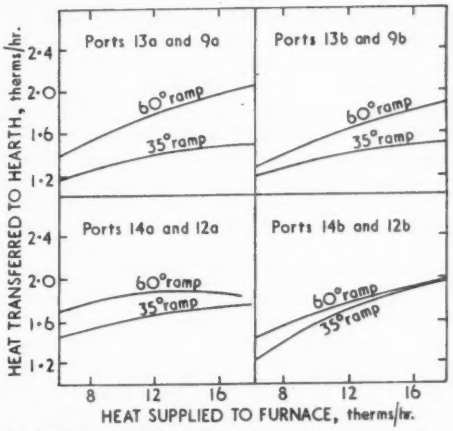

Fig. 6—Effect of steepening the roof ramp. Furnace pressure 0·02 in. W.G.; theoretical air

efficiency in addition to that caused by velocity alone, it is possible to use larger gas ports without sacrificing performance. This is of special importance in plants in which gas pressure is low. Attempts to improve performance by decreasing the gas-port size may in practice lead to a loss of efficiency, particularly if the air/fuel ratio is not controlled : in modern plants such conditions are less frequently encountered. On the other hand, a large gas port should, theoretically, give a larger radiating surface ; thus, provided that the flame is equally intense and hot, such a port would be advantageous.

Much work remains to be done on the effect of gas-port size, in particular its effect on the flow pattern within the melting chamber, the importance of which has been demonstrated by Chesters and his co-workers.[5]

Effect of Air-Ramp Slope

Figure 6 shows that a steepening of the air ramp gave improved results ; this is less marked with the gas ports right back in the wall (ports 12 and 14) than with the ports well forward (9 and 13). Such a steep ramp may involve constructional difficulties

Table II

EFFECT OF GAS-PORT SIZE

Probable Mixing Mechanism	Port No.	Theoretical Air		55% Excess Air	
		Furnace Pressure, in. W.G.		Furnace Pressure, in. W.G.	
		+0·02	+0·06	+0·02	+0·06
Mainly velocity difference between gas and air	9	Equal	S	L	L
	10	S	S	(L)	(L)
	11	S	S	(S)	Equal
	12	S*	S*	Equal	Equal
Velocity difference together with impingement	13	L	L	L	L
	14	L	S*	L	S
Mainly impingement	15	S	L	S low flow L high flow	L
	16	L	L	...	...

* Except at lowest flows

in practice, but it may be worth consideration. A steepening of the air ramp has less effect with a small port—if a port is already giving good mixing, either by high velocity or a high angle of impingement (steep ramp), any other change towards better mixing will have less effect. Steepening the ramps, however, usually involves a reduction in the area of the Venturi 'throat' and the improved performance may be partly brought about by this restriction. In practice, refractory wear may arise from such a restricted throat.

Effect of Position of Gas-Port Nose

One of the major objects of the present series of experiments was to observe the effect of moving the gas port back within an ordinary Venturi construction. This effect is shown in Fig. 7 : ports 9–12 denote successive backward movements of the gas port with a 35° air ramp, and ports 13 and 14 are extreme positions of the gas port (fully forward or fully back) with a 60° air ramp.

In general, a successive improvement is found as the port is moved back. Although each curve is obtained from experimental points which show some scatter, and since the difference between extreme curves (ports 9 and 12) is large enough to be significant and the intermediate ports take up the expected positions, the small differences between adjacent curves may also be regarded as significant. The successive improvement is less marked with 55% excess air, and some of the intermediate curves (*e.g.*, for ports 10 and 11) show an inversion, but little significance can be attached to this. The use of appreciable amounts of excess air tends to obscure the effect of any particular variable under study.

In general, the effect of moving the gas port back is similar with a 60° air ramp, although its magnitude is less. Sometimes, particularly with the large gas port, there is an inversion at high flows, this being more marked with excess air and high furnace pressures. This may result from the abnormal flow pattern that occurs when a relatively large amount of gas and air is being discharged into the port side of the restricted throat, which arises from the use of a 60° roof ramp : the divergent flame jet from a large port, itself set well back, may hit the restricted throat. Provided, therefore, that there is no obstacle to the normal travel of the flame through the furnace, the gas port in a furnace of the Venturi type should, in general, be set well back.*

Collins and Tyler,[6] who investigated mixing phenomena in laboratory-scale models, also found that, at any fixed plane across the furnace chamber, mixing became more complete as the gas port was moved back. By comparing complete mixing patterns, however, these investigators concluded that moving the gas port back did not lead to an intrinsic improvement in the mixing properties of the port system itself, but

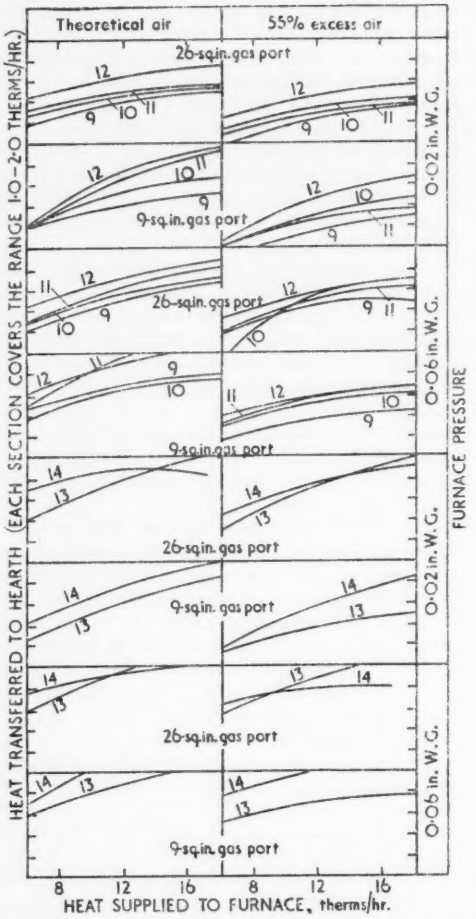

Fig. 7—Effect of gas-port position. Ports 9–12 have a 35° air ramp and ports 13 and 14 have a 60° air ramp

the whole unchanged pattern was moved back bodily so that when the gas and air streams reached the melting chamber itself, mixing was more advanced.

The present experiments show that this effect of the gas-port position is reflected in a greater heat transfer to the hearth as the port is moved back.

Port Design

Certain other more radical changes in port design were also tested. In Part III, the results of a special port (No. 8), in which a 'cowl' was superimposed in a single central air uptake, were outstanding. However, it was realized that such a port, which in effect was a small precombustion chamber, would hardly be practicable in a production furnace because of the probability of excessive refractory wear. A similar port has, however, been tried in the U.S.A. although little information on its performance is available.[7] In the present series of experiments a port combining the single air uptake with a steep air ramp was designed (ports 15 and 16) to reproduce the highly efficient mixing conditions of port 8, without using a restricted premixing chamber with its associated

* It is self-evident that, taken to extremes, a port can be set too far back so that the flame spends itself before reaching the outgoing port and the outgoing end of the furnace becomes cold. There is some evidence that this has happened in certain oil-fired furnaces where the design has permitted extreme withdrawal of the oil gun. Theoretically in such a position more fuel could be burnt and the production rate increased, although in practice this is not always possible.

refractory wear. Port 16 had a smaller single uptake than port 15. Figure 2 shows that these ports gave results at least equal to those obtained with port 8.

The pronounced 'wing walls' or 'monkey walls,' which were built into these ports, appear to have an appreciable effect; when some of the experiments were repeated with the wing walls removed the heat-transfer curves were inferior (*see* Figs. 2*p* and *q*).

Various cowls similar to that used in port 8 were tried in conjunction with ports 15 and 16, but with indifferent results. The simple combination of a steep ramp with a single uptake clearly offers the most promising results among the designs so far tried. It is hoped to arrange trials in a full-scale production furnace to reveal any unexpected practical difficulties.

Roof Temperatures

Although certain port designs, studied both in the present series of experiments and in earlier work, have given high rates of heat transfer to the hearth, there is no guarantee that such designs would be best under practical operation without some indication whether unduly high roof temperatures are also attained. The possible relationship between roof temperatures reached in the experiments (which were conducted below steelmaking temperatures) and roof temperatures reached in practice has already been discussed[4]: as a rough approximation the range 900–950° C. is regarded as the 'equivalent safe roof temperature' in the present model working at sub-steelmaking-temperature levels. The maximum roof temperature governs the rate at which the furnace can be driven, the average roof temperature governs the actual rate of working, and the range between minimum and maximum temperature is a measure of the efficiency of combustion and the uniformity of the flame.

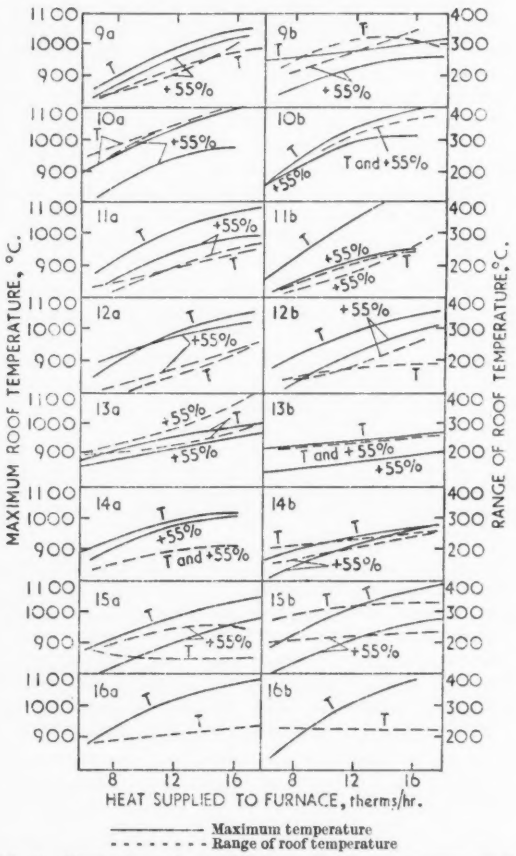

Fig. 8—Variation of maximum roof temperature and range of temperature with heat input for various port designs. Air/gas ratio (theoretical *T* or 55% excess) given on curves

The influence of furnace-operating conditions on roof temperature is almost exactly similar to their influence on the heat transfer to the hearth, and the curves of roof temperature reproduced in Fig. 8 resemble very closely the heat-transfer curves in Fig. 2. The results of these observations may be summarized as follows:

(i) In all cases, as the heat input increases both the maximum and average roof temperature also increase

(ii) In all cases, excess air cools the roof. The cooling effect of excess air is made greater with (*a*) port designs with a steep ramp (which suggests a directive influence on the flame, keeping it at hearth level) and (*b*) port designs where mixing of air and gas is assisted by impingement of the air and gas streams at a large angle

(iii) In some cases excess air may assist the attainment of maximum heat transfer to the hearth without exceeding a safe roof temperature (*see* Table III) but at the expense of fuel consumption

(iv) As a corollary to (i), increasing the roof pressure (which has the effect of increasing the heat transfer to the hearth) increases the roof temperature

(v) A marked steepening of the roof ramp at the end reduces roof temperature. This may result from the increased directive effect of the air stream ('keeping the flame down') and/or from modified recirculation effects

(vi) The ports giving more efficient combustion also increase the uniformity of roof temperature.

Perhaps the most interesting conclusion is that under certain circumstances excess air permits a greater heat transfer to the hearth, without exceeding a specified roof temperature, than would otherwise be the case. In Table III, the ports are placed in order of greatest heat transfer to the hearth without exceeding the 'equivalent safe roof temperature' of 950° C.

In most heat-exchange systems the heat consumption per unit of throughput is usually assumed to decrease as the rate of throughput increases, but in open-hearth furnace practice, the lowest heat consumption per ingot ton* is obtained with older slow-working furnaces; the faster-working furnaces attain their high rate of production, at least partly, because the roof is protected by excess air.

In the earlier work (*see* Table I, Part IV),[4] the only port giving a heat transfer to the hearth of more than 2 therms/hr. without exceeding the safe roof temperature was design 8, which is regarded as one which would not be practicable in a production furnace. Table III shows that port 15 (*see* Fig. 1) which was designed as a practical version of port 8, closely

* Other things being equal, *e.g.*, whether or not hot metal is used.

Table III

HEAT TRANSFER TO HEARTH

(Maximum roof temperature 950° C. Furnace pressure + 0·02 in. W.G.)

Design No.	Excess Air, %	Heat to Bath, therms/hr.	Heat Input, therms/hr.
15b	0	2·00	9·3
15a	55	1·95	14·9
14b	55	1·94	14·7
15b	55	1·90	15·2
13a	55	1·88	15·0
14b	0	1·85	13·6
14a	0	1·85	8·4
15a	0	1·82	10·0
14a	55	1·69	9·8
13a	0	1·65	9·1
13b	0	1·63	12·0
12a	0	1·62	10·4
12b	0	1·62	9·6
12b	55	1·54	13·6
11b	0	1·47	8·7
12a	55	1·44	10·7
11a	0	1·42	8·4
10b	0	1·37	7·6
10a	0	1·37	7·8
11b	55	1·36	16·5
9a	0	1·35	10·2
10a	55	1·34	12·0
11a	55	1·32	12·6
10b	55	1·30	12·0
9a	55	1·29	11·8
9b	0	1·20	6·0
9b	55	1·18	14·0

approaches this degree of efficiency. This efficiency is also closely approached by ports 13 and 14. The high result with port 15*b* is exceptional in that it is attained with theoretical air and a rather low heat input, whereas the other top positions in Table III represent conditions of excess air.

CONCLUSIONS

The following conclusions may be drawn from the examination of the Venturi port :

(1) Observed results for air/gas ratio and furnace pressure are similar to those recorded in previous papers in this series—the use of theoretical air and high furnace pressure is beneficial to heat transfer.

(2) Improved results are obtained by moving the nose of the gas port back and by steepening the roof ramp.

(3) When roof temperatures are taken into account, these conclusions are modified slightly : a moderate excess of air can cool the roof and so permit a higher rate of driving and an increased heat transfer to the hearth without damage to the roof. (The cost of the extra fuel is presumably more than regained in the increased output.)

(4) The more efficient port designs are more sensitive to correct operating conditions than are poor designs. As the design of the furnace is improved, instrumentation and automatic control become increasingly important.

Acknowledgments

The author thanks the management of the Shelton Iron, Steel, and Coal Co., Ltd., for its continued support and provision of experimental facilities. His thanks are also due to Dr. A. H. Leckie, under whose general supervision the programme was carried out, and to Mr. M. P. Newby and his colleagues of the B.I.S.R.A. Physics Department for advice. The experimental work was carried out by the author assisted by Messrs. E. D. H. Booth, J. H. Cook, R. P. Shaw, and R. P. Udall.

PART VI—SUMMARY OF RESULTS AND THEIR APPLICATION IN PRACTICE

By J. R. Hall and A. H. Leckie, Ph.D.

SYNOPSIS

The extent to which the experimental results obtained on the small-scale furnace, operated by the British Iron and Steel Research Association at the works of the Shelton Iron, Steel and Coal Co., Ltd., have been applied in practice, is summarized. Arrangements for future investigations of open-hearth furnace combustion problems are briefly outlined.

THE previous papers in this series have outlined the experimental results obtained on the $\frac{1}{5}$-scale furnace operated by the British Iron and Steel Research Association at the works of the Shelton Iron, Steel and Coal Co., Ltd. The practical results were first applied in the Shelton production shop, but early in the experiments the fuel supply position made it necessary to convert the Shelton production shop to oil-firing ; thus the results from the model furnace, primarily designed for work with lean-gas firing (producer gas or mixed gas), ceased, in some respects, to be directly applicable. Nevertheless, many of the main conclusions reached apply equally well to all fuels, and one of the major developments arising out of this experimental work—the use of a single air uptake at each end instead of the more usual two—appears to be more successful with oil-firing than with gas-firing. No attempt was made to conduct experiments with oil burners on the Shelton model furnace because, during most of the period of the experiments, it was thought that it was impossible to scale-down oil burners ; later work by other investigators has indicated that this may be possible. The Shelton plant has, however, been fully occupied

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throughout in studying only a proportion of the field of gas-firing.

The extent to which the information obtained during the period covered by the experiments on the Shelton furnace has been applied in practice is summarized in this paper.

OPERATION FACTORS

Air/Fuel Ratio

The greatest heat transfer to the hearth for a given heat input is attained when theoretical air is used. This is in accord with theory. It has also been found that under some conditions maximum heat transfer to the hearth, whilst not exceeding a given roof temperature, is attained when excess air is used, and that with less efficient port designs, excess air can bring about more complete combustion at high fuel rates.

These last two factors account for the fact that in normal open-hearth practice the use of a moderate excess of air (10–20%) gives the best results. Attempts to eliminate all excess air may lead either to inefficient combustion or to damage to the refractories. One of the aims of future work on furnace design is to determine the pattern of port and melting chamber which will permit complete combustion and minimum damage to the refractories with minimum excess air. Many present-day furnaces rely on excess air or air infiltration to minimize refractory wear. In production furnaces some air is used for chemical oxidation,* so that the minimum amount of air required at the air port is probably rather higher than the theoretical amount.

Furnace operators have for long been aware of the discrepancy between the apparent need to use excess air in practice and the theoretical desirability of eliminating excess air. In the Shelton shop, meters for both fuel and air have been used since 1936 but attempts to control the air/fuel ratio in practice are handicapped because it is not yet possible to continuously record the actual air flow in the furnace uptakes. Air meters can record only the air entering the regenerative furnace system, and by the time this air has passed through the reversing valves and brick regenerators, the combined effect of loss (mainly at the reversing valve through direct short circuiting to the stack) and infiltration (to the regenerators and flues) may make the true air flow appreciably different from that metered. Recent work[8] in which the air flow in the uptakes has been measured directly by a water-cooled Pitot tube suggests that under favourable conditions these two errors may almost cancel out so that the uptake air flow is, in fact, quite close to the metered flow ; this fortuitous result is, however, hardly a satisfactory solution.

Full application in practice of the conclusions reached on the air/fuel ratio from the model work, must await advances in furnace engineering, but if it is found that a large excess of air is necessary to keep the roof cool, or to obtain efficient combustion, there is some serious fault in the design. With the more efficient ports, such as the single-uptake patterns discussed in Part III and Part IV and elsewhere,[3, 4, 9] no excess air should be necessary to ensure complete combustion, although some may still be required to attain high production rates without damage to the roof.

These conclusions apply equally to gas-fired and liquid-fuel-fired furnaces. In the Shelton production shop, now completely converted to oil, air is run at a constant rate throughout the charge. After a rebuild, waste gas analyses are taken at stage level at a maximum oil flow (320 gal./hr.) and the combustion air and draughting conditions are set to give 3–6% of oxygen in the waste gases ; these conditions are checked at intervals throughout the operation. Best results are obtained with 15–30% of excess air when operating at a maximum fuel rate. In the manufacture of medium- and low-carbon steels and in the absence of fully automatic control, the model-furnace results provide some justification for the use of a constant air flow throughout a charge instead of controlling the air/fuel ratio throughout. Since it appears that excess air can exert an important cooling effect on the roof, it would be reasonable to use more excess air during the refining period when the risk of overheating the roof is often greater.* If the ratio is based on the maximum fuel rate used during charging and melting, the air/fuel ratio will automatically increase when the fuel rate is decreased later in the heat. However, with the increased application of automatic control to open-hearth furnaces it is possible to foresee the use of programme controllers to change a controlled air/fuel ratio to the correct value at different stages of the heat.

Furnace Pressure

The thermal benefits to be obtained from keeping the furnace pressure (*i.e.*, the pressure in the furnace chamber itself, as measured at the roof or at a point in the wall, and not the pressure in any other part of the system) as high as practicable, have been illustrated in the model experiments (*see* Figs. 5 and 6 (Part II), Fig. 4 (Part III), and Fig. 4 (Part V). Heat-transfer efficiency continues to improve even after the roof pressure has reached a mean value, which should exclude all air infiltration when calculated on a static pressure basis. This may be partly caused by pressure oscillations, but it is probably mainly a result of the injector effect of the fuel jet which is particularly marked with oil-firing.

In a series of experiments carried out on one of the Shelton production furnaces, in which the incoming air flowing in the uptakes was measured directly using a water-cooled Pitot tube,[8] it was found that with the air valve closed and the fuel oil shut off, little or no air flowed in the uptake, but when the oil was turned on, even although the air valve remained

* The ' chemical potential ' of oxygen necessary to completely oxidize CO to CO_2 is higher than that required to completely oxidize Fe to FeO at steelmaking temperatures. This is only of academic importance since the rapid formation of an oxide layer protects the iron and makes it possible to melt steel in an open-hearth furnace with high efficiency of combustion. Nevertheless, this must be borne in mind when designing special forms of steel-melting units.

* This is apart from the risk, mainly present during charging, of ' burning ' the roof by flame deflection from piled-up scrap ; this however, is a matter for vigilance on the part of the furnace and charger crews and does not influence the arguments on which control methods may be based.

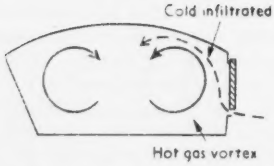

Fig. 1—Existence of two opposing vortices

closed, a substantial flow appeared in the air uptake. This suggests that even if the calculated static pressure in the furnace is sufficiently high to exclude all air infiltration, the injector effect of the fuel jet can appreciably reduce the furnace pressure at the walls, necessitating still higher furnace pressures if infiltration is to be stopped.

The model experiments have confirmed and given a greater understanding of the advantage of a moderately high controlled pressure. In the model work it was recognized that, in practice, a roof pressure high enough to eliminate air infiltration would probably lead to such excessive flame 'sting' that serious damage would be caused. Thus the furnace designers should aim to secure better-fitting doors, etc., so that higher roof pressures can be carried safely, and to improve melting-chamber design so that, to keep the roof cool, infiltrated air is unnecessary.

In this connection flow-pattern work of the type carried out by Chesters and his colleagues[5] should be useful. Chesters shows that in many furnaces it is likely that two opposing vortices exist as shown in Fig. 1, which is derived from Chesters' paper, and it seems reasonable to assume that the vortex on the doorside will carry with it air infiltration below a door and so protect the roof near the front wall. Since there are generally no door-sill gaps in the back wall, the roof near the back wall does not gain cold-air protection in this way. This may be one reason why wear is worse towards the back wall.

PORT DESIGN

The initial experiments confirmed previous views that with conventional port designs of the air-over-gas type, a small port (high gas velocity with high pressure behind the port) gave better results as was already well known in the industry. An early experiment (port 12, Part II) showed that high air velocity (such as would be obtained from pressure air introduced through two small nozzles) would give excellent combustion, but this is not of practical importance for reversing regenerative furnaces, which need large ports to handle waste gases.

Later, port designs were developed in which a high inherent mixing efficiency was obtained by allowing the air to enter the furnace direct from below in ports of the Maerz or 'single-uptake' types. In these ports the advantages of a high initial velocity were not so clearly marked, and in some cases a large port appeared to be slightly superior. This is only to be expected, since, if means other than the use of high velocity are used to attain equally rapid mixing and combustion intensity, irrespective of the port size, the larger radiating surface of a flame issuing from a large port would be expected to show some advantages.

This is an important result because the attainment of high port velocity in a producer-gas-fired furnace necessitates modifications to the producer plant to produce good gas at a pressure of 4 in. W.G. or higher. If similar or better results can be obtained by modifying the port design without modifying the producer plant, this may be preferable; such a course is also desirable if a plant has inadequate producer capacity resulting in permanently low gas pressure.

The most effective modification in port design is probably the single-uptake furnace, which was discussed by the Steel Practice Committee at the start of the experiments and which was tried in the course of the programme. A brief outline of the features of this type of furnace, in which the two air uptakes usually found at each end of the furnace are replaced by one, has already been published.[3, 4, 9] This experimental work, fully described in Parts III–V (port designs 4–8 and 15–16), indicated that a single-uptake furnace merited a trial on a production scale. Preliminary tests show that in practice the single-uptake furnace is more successful with liquid-fuel-firing than with gas-firing.

A 60-ton producer-gas-fired furnace in the works of Messrs. Steel Peech and Tozer, converted to a single-uptake, initially gave a very satisfactory production rate, fuel consumption, and roof life, but considerable trouble was experienced with wear at the top of the uptake. This trouble may have been caused by downward radiation from the intense early-developed flame; this trouble is not experienced with oil-fired furnaces because the small jet results in a flame of much smaller radiating area. This maintenance difficulty led to a temporary abandonment of the trials with the producer-gas-fired furnace, in spite of its generally favourable performance in other respects. However, no such troubles were encountered with oil-fired furnaces converted to single-uptake, and the results were entirely favourable. The production furnaces at Shelton were among the first to be converted to single-uptake furnaces.

MELTING SHOP AT SHELTON

The melting shop of the Shelton Iron, Steel and Coal Co., Ltd., at present consists of four fixed furnaces, three of 60-tons nominal capacity and 75-tons actual capacity, and one of 50-tons nominal and 72-tons actual. There is also an 80-ton tilting furnace. It is a hot-metal shop, direct metal being taken from the blast-furnace in a proportion varying according to the availability of raw materials. At the time of writing the proportion was 28% of direct blast-furnace iron, 6% of cold iron, and 66% of scrap. The use of direct blast-furnace metal instead of a mixer is largely associated with local site conditions. The main product is 0·2% carbon mild steel with about 10% of rail and spring steels, occasionally with some low-carbon rimming steel.

The shop was built between 1905 and 1911, and since then the site has become greatly congested, with the result that traffic handling presents problems, which must be borne in mind when considering the output figures.

Until 1947 the shop was fired with producer gas from a battery of 6 Kerpely and 3 Morgan gas-producers. Kent recorders for crude producer gas,

air meters, and Foster radiation-type roof-temperature recorders have been in use since 1938. The Shelton melting shop was probably a pioneer in the use of roof pyrometry for control purposes. In 1939, experiments were made in which the gas flow to the steel furnaces was automatically controlled from the roof temperature, but means of overcoming the 'hunting' occurring with this type of control had not then been developed and the experiments were not continued. This was, however, probably the first attempt to apply a technique which, with modern developments in automatic control, is now successfully used in several works.

Under producer-gas-firing the shop output, when working all furnaces, averaged 4700 tons/week, the best output being 5162 tons; fuel consumption averaged 5·5 cwt./ton. Because of changes in the fuel supply position, in 1947 the shop was converted to oil-firing with the conventional two air-uptake type of construction. Under these conditions output was 5228 tons/week and fuel consumption was 38 gal./ton. As a result of the model work carried out on the works site the '*F*' furnace was converted to a single-uptake design in 1949.

'*F*' Furnace Conversion

This furnace was originally a conventional twin-uptake producer-gas-fired furnace. On conversion to oil-firing the dog-house principle was adopted, but it was soon apparent that the burner was too near the charge, causing heavy wear and tear to the linings and roof. The dog-house was therefore eliminated and the burner was brought through the end wall, thus, in effect, bringing the air immediately to either side of the flame. For conversion to a single-uptake design, the cast-iron chill, which originally carried the gas port, was removed, leaving the end of the furnace down to the slag pockets unobstructed. A central single uptake was then easily constructed.

The results obtained on the '*F*' furnace were so promising that the other furnaces were converted as top repair became necessary. Conversion of the shop was complete in 1950 and, before the shortage of raw materials caused some slowing up of production, the average output was 6163 tons/week, without any significant change in oil consumption.

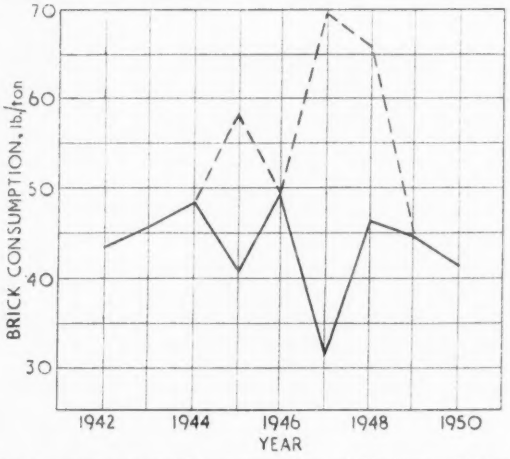

Fig. 2—Furnace-brick consumption at Shelton. (Major rebuilds included in broken curve and excluded in full-line curve)

It is difficult to assess the effect of change of design on refractory consumption because the latter is influenced by many factors, including the incidence of major furnace rebuilds. A curve of refractory consumption for the past nine years (Fig. 2) shows the influence of factors such as the conditions existing towards the end of the war. A downward trend during the last few years, including the period covering the change in furnace design, is indicated.

The use of the single-uptake is now fairly widespread—in this country there are now about 20 single-uptake furnaces in production in 11 different works, and there are several others abroad. Additional conversions continue to be made. The single-uptake '*J*' furnace at the Redcar works of Messrs. Dorman, Long and Co., Ltd., averaged 1661 tons/week at an average oil consumption of 24¼ gal./ton compared with a shop average of similar-size conventional furnaces of 1425 tons/week and 26½ gal./ton. Other furnaces in this shop are now being converted.

In a few works a conversion to a single uptake has been unsatisfactory because so far most conversions have been top-rebuilds on an existing base, and it is not always possible to proportion the uptake correctly. The use of a single uptake often permits the use of a very large area, but the burner may be too far from the bath, leading to refractory wear at the incoming end and chilling at the outgoing end. This is confirmed by American experience.[10] The uptake should not be much larger than that required to handle the maximum quantity of hot air and waste gases as calculated from the pressure and draught available.

At Shelton, it has not yet been possible to try the combination of single uptake and steep roof ramp, which gave such good results on the model, since the steep ramp would increase furnace height to an extent that would foul the crane tracks.

FUTURE WORK

Future work will be carried out on a smaller furnace being built in the Association's Steelmaking Laboratory, Sheffield, because it is now known[6] that useful results of the kind obtained from the Shelton furnace can be obtained on smaller models. The work of Chesters and his colleagues,[5] although carried out with different objectives, also justifies laboratory-scale model work. The Shelton furnace was subject to the type of difficulties associated with large-scale practice, *e.g.*, maintenance of brickwork, scaling and burning away of metal parts, and similar difficulties, which made the continued maintenance of a satisfactory standard of accuracy difficult. The use of a smaller model, operated on a site provided with full research laboratory facilities, should permit a more rapid rate of working and quicker changes in design, so that further progress can be made on the many outstanding problems, such as the optimum slope and shape of roof ramps.

It will be clearly necessary to relate heat-transfer results with flow pattern in the same model, refractory wear, and waste-gas and radiation losses

Nevertheless, the results already obtained have justified the expense of erecting and operating the model and the efforts of the operating staff and of the company supporting the work.

Acknowledgments

At each stage in this work special acknowledgment has been made to the Shelton Iron, Steel and Coal Co., Ltd., for its part in the work. Although the operation of the model was in the hands of the staff of the British Iron and Steel Research Association's Steelmaking Division, all repairs and alterations to the model were carried out by the Company, which also provided all the fuel at no charge to B.I.S.R.A. Special acknowledgment is made to the Directors of the Company for authorizing this research effort, and for their enthusiastic support throughout.

Thanks are also due to the Steel Practice Committee for its interest and encouragement, and for the many items of helpful advice received from the members.

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A Microscopical Examination of Iron Containing Manganous Inclusions

By R. E. Lismer, A.Met., A.I.M., and F. B. Pickering, A.Met., L.I.M.

SYNOPSIS

A further microscopical study of inclusions of (Mn, Fe)O, has been undertaken to confirm and enlarge the conclusions reached by Sloman and Evans. Samples of three ingots containing inclusions of varied MnO content have been examined under normal vertical illumination, under polarized light, after the application of Whiteley's tests, and after acid tests. The optical and chemical characteristics of the inclusions have been determined.

THE microscopical appearance of inclusions of the double oxide (Mn, Fe)O, described by Sloman and Evans,[1] showed that their colour and form varied continuously as the proportion of MnO increased from about 25% to almost 100%.

During discussion of that paper by the Solid Steel Study Group (of the Gases and Non-Metallics Sub-Committee), it was decided that confirmatory microscopical examination of selected samples of the series studied by Sloman and Evans[1] should be undertaken by the Group. Examination was primarily confined to purely visual methods, but it was later decided that a more detailed and systematic examination should be attempted to determine the optical and chemical characteristics of the inclusions.

MATERIALS EXAMINED

Samples were taken from ingots *H* and *K* of the series described by Sloman and Evans, and from an additional specially made ingot (ingot *L*). The chemical constitutions of the inclusions in these ingots, were :

Ingot *H* : over 95% MnO
Ingot *K* : approx. 25–30% MnO
Ingot *L* : approx. 60% MnO.

The inclusions were mainly solid solutions of MnO and FeO, with some extraneous SiO_2 and Al_2O_3. Ingot *L* appeared to contain some MnS also.

POLISHING TECHNIQUE

The specimens were ground manually down to 00 emery paper and then wheel-polished on Melton cloth impregnated with chromic oxide. They were finally wheel-polished on Selvyt cloth impregnated with alumina. A light etch in alcoholic 2% nitric acid was used as desired.

A modification of this technique, sometimes found useful with soft materials, was to polish manually on a stationary Selvyt cloth treated with a suspension of alumina in a fairly concentrated soap solution. By this method a light nitric acid etch could be easily removed, and the inclusions obtained in an almost scratch-free matrix.

Prolonged manual polishing often resulted in the inclusions being pitted out.

METHOD OF EXAMINATION

The following methods were employed :

(*a*) Normal vertical illumination, specimens both unetched and lightly etched in 2% nital.

Paper SM/BB/59/51 of the Gases and Non-Metallics Sub-Committee of the Steelmaking Division of the British Iron and Steel Research Association, received 8th August, 1951.

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Fig. 1—Angular inclusions in a MnO-rich solid solution of (MnO, FeO), (Ingot *H*): (*a*) Angular translucent particle; (*b*) highly translucent drop attached to corner of angular particle ; (*c*) typical dendritic form ; (*d*) large translucent inclusion showing inner opaque particle

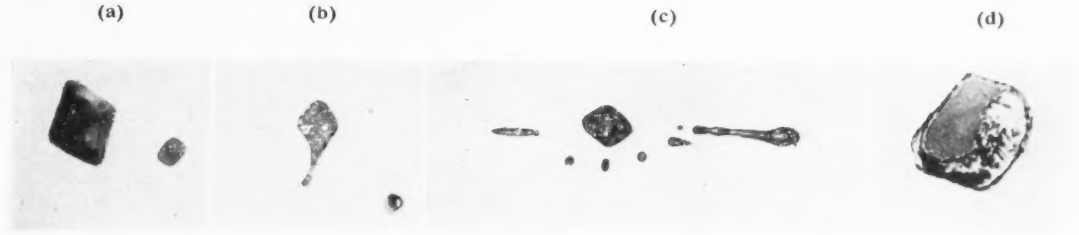

Fig. 2—Spherical inclusions in a FeO-rich solid solution of (MnO, FeO), (Ingot *K*): (*a*) Monophased spherical inclusion ; (*b*) inclusion showing inner metallic particle ; (*c*) metallic particle at periphery of inclusion ; (*d*) metallic particle pitted out ; (*e*) same inclusion as *2b* after etching, showing metallic particle pitted out

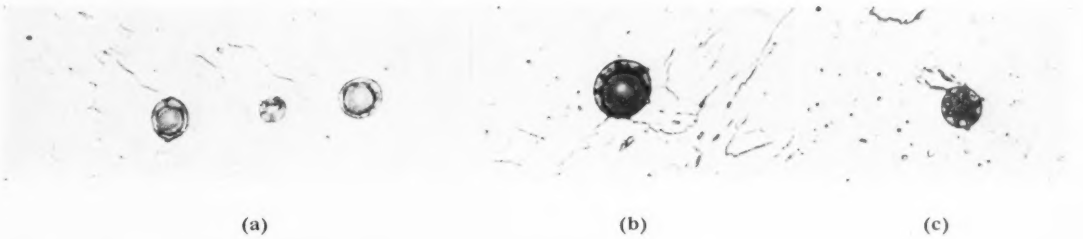

Fig. 3—Multi-phased inclusions in solid solution of (MnO, FeO) with medium MnO content (Ingot *L*) : (*a*) Globular inclusions, two-phase with third phase consisting of particles in the annulus ; (*b*) similar inclusion, central translucent particle in darker grey globule which contains several particles ; (*c*) semi-spherical particles within a monophased inclusion

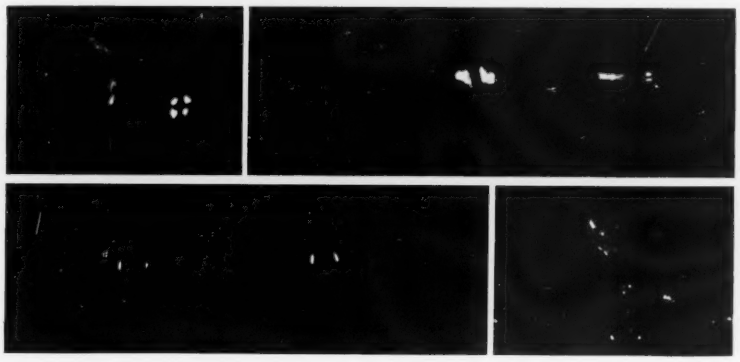

Fig. 4—Inclusions examined under polarised light : (*a*) Same inclusion as *1a* ; (*b*) same inclusion as *1c* ; (*c*) same inclusion as *3a* ; (*d*) same inclusion as *3c*

Magnification in each case × 1000

[*Lismer and Pickering*
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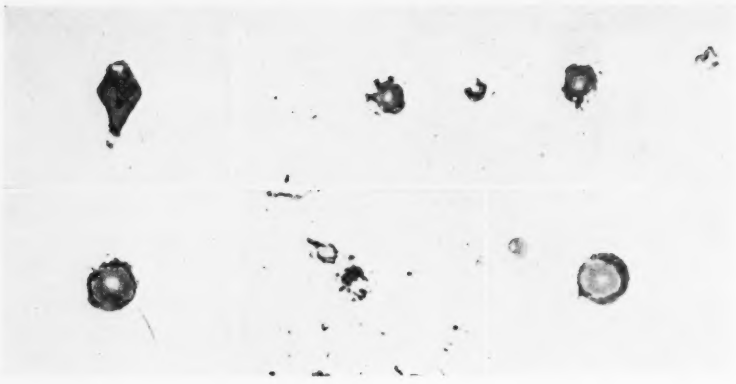
(a) (b)



(c) (d) (e)

Fig. 5—Inclusions examined after application of Whiteley's test : (*a*) Same inclusions as 1*b* ; (*b*) same inclusion as 3*a* and 4*c* ; (*c*) same inclusion as 3*b* ; (*d*) same inclusion as 3*c* and 4*d* ; (*e*) duplex inclusion showing no reaction to Whiteley's test (Ingot *L*)

(a)

(b)

(c)

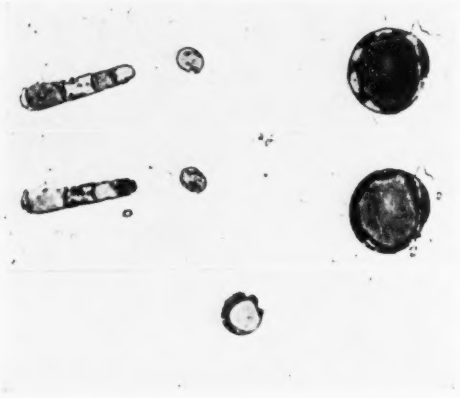
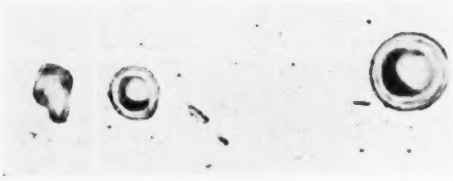


Fig. 6—Inclusions showing the effect of etching in chromic acid (Ingot *L*) : (*a*) Duplex inclusions of oxide and sulphide before etching ; (*b*) same inclusions as 6*a* after etching ; (*c*) inclusion showing non-attack by the acid



(a) (b)

Fig. 7—Inclusions showing the effect of etching in hydrochloric acid : (*a*) Almost complete attack on MnO-rich solid solution (Ingot *H*) ; (*b*) complete attack on FeO-rich solid solution (Ingot *K*)

Magnification in each case × 1000

Lismer and Pickering]
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(*b*) Polarized light.
(*c*) Whiteley's silver nitrate test for sulphides.[2]
(*d*) Etched in alcoholic 10% nitric acid.
(*e*) Etched in 10% chromic acid in water.
(*f*) Etched in 5% hydrochloric acid in alcohol.

Normal vertical illumination revealed the degree of opacity of an inclusion, and its colour under reflected light. Polarized light, besides revealing whether an inclusion was anisotropic, also helped to determine the colour under transmitted light of isotropic cubic inclusions.

Apart from Whiteley's silver nitrate test for sulphides, the other etching reagents are given in a table published in "Metals Handbook,"[3] a modification of a similar table put forward by Wohrman,[4] based on an orginal scheme proposed by Campbell and Comstock.[5]

EXPERIMENTAL RESULTS

A summary of the experimental results is given in Table I; the following is a more detailed description.

Examination under Normal Vertical Illumination

Ingot H—Most of the inclusions were angular, dark-grey, and sufficiently translucent to show internal reflections which were blue-green (Fig. 1*a*). After standing in a desiccator the inclusions darkened considerably, as noted by Benedicks and Lofquist,[6] because of the formation of MnO_2 on the inclusion surface. A light etch in 2% nitric acid in alcohol either partially or completely removed this effect.

A predominant shape was a diamond with a droplet of very translucent material attached to one corner (Fig. 1*b*). Very occasionally a highly dendritic form (Fig. 1*c*) and a large translucent inclusion exhibiting an inner opaque particle (Fig. 1*d*) were observed.

Ingot K—Almost all the inclusions were monophased, spherical or ovoid, light-grey, opaque particles of two main forms:

(i) Single-phase spherical or ovoid (Fig. 2*a*).
(ii) Similar, but showing a rounded metallic particle, presumably ferrite, within the inclusion (Fig. 2*b*). This metallic portion sometimes reached the periphery (Fig. 2*c*) and overpolishing and etching were observed to pit out the inner metallic particle (Figs. 2*d* and *e*). Fig. 2*e* illustrates the same inclusion as Fig. 2*b* after etching.

Several larger duplex globular inclusions were present which exhibited darker angular particles within the large light-grey spheroid.

Ingot L—The inclusions were mainly three-phased and globular, although some were elongated, and contained large, possibly extraneous, duplex particles.

Most of the inclusions consisted of a globular translucent grey central particle, that occasionally showed green by reflected light, within an outer globule often darker grey in colour (Fig. 3*a*). In the annulus of the outer particle, small circular or hemispherical light-grey particles were often present (Figs. 3*a* and *b*); these occasionally occurred within a monophased grey globule (Fig. 3*c*).

Summarizing, the inclusions are: mainly angular or dendritic, dark-grey, and translucent with green-blue internal reflections when rich in MnO; lighter grey, opaque and mainly circular, occasionally containing a metallic particle within them, when rich in FeO; multi-phased but of indeterminate nature when of medium MnO content.

Examination under Polarized Light

Ingot H—The translucent inclusions appeared bright green and the more rounded particles showed a typical 'cross' effect. This is illustrated in Figs. 4*a* and *b*, which are the same inclusions as in Figs. 1*a* and *c* respectively.

Ingot K—These particles were completely opaque, although some of the pits showed up bright under polarized light.

Ingot L—The central particles of the three-phased inclusions were opaque, but the more translucent annulus exhibited a green colour with a typical 'cross' effect, as in Fig. 4*c*, which shows the same inclusion as Fig. 3*a*. In the inclusions containing small round or hemispherical particles, the latter polarized individually with a 'cross' effect, as in Fig. 4*d* (the same inclusion as in Fig. 3*c*).

This polarizing effect of the small particles is interesting, especially as earlier co-operative microscopical work indicated that they were sulphides. However, in a list of the properties of common inclusions contained in "Metals Handbook,"[3] MnS is said to appear green under polarized light, and this was

Table I

IDENTIFICATION OF INCLUSIONS IN IRON-MANGANESE-OXYGEN ALLOYS

Type of Inclusion	Usual Form	Opacity	Colour under Normal Light	Appearance under Polarized Light	Reaction to:			
					Whiteley's Test	10% Alcoholic Nitric Acid	10% Chromic Acid in Water	5% Alcoholic Hydrochloric Acid
Solid solution of (Mn, Fe) O, rich in MnO (Over 95 % MnO)	Angular or dendritic and very occasionally rounded.	Quite translucent, may become darker and more opaque on standing.	Blue-green internal reflections or dark-grey when less translucent.	Green	No reaction	No reaction but may become more translucent.	No reaction	More or less completely attacked.
Solid solution of (Mn, Fe) O, rich in FeO (25–30% MnO)	Globular, spheroidal or ovoid. May be pitted in centre due to iron particles pitting out.	Opaque	Light-grey	Black	No reaction	No reaction but stands in heightened relief.	No reaction	Completely attacked and dissolved out
Solid solution of (Mn, Fe) O, with about 60% MnO.	Globular or elongated, sometimes two-phased.	Varying from opaque to translucent.	Varying shades of grey.	Sometimes green, often black.	No reaction	No reaction	No reaction	Completely attacked.
Sulphide (MnS), associated with 60% MnO solid solution.	Small, light-grey, globular or hemispherical within oxide inclusions.		Light dove grey.	Green with typical 'cross' appearance.	Whitened by the application of Whiteley's test.	No reaction	Sulphide part of duplex inclusions attacked.	Removed together with oxide component.

confirmed by examination of a sample of free-cutting steel containing many MnS particles..

Application of Whiteley's Test for Sulphides[2]

The use of a Selvyt cloth impregnated with a solution of silver nitrate has for some years been considered an excellent test for the identity of sulphides.

Ingot H—Generally no reaction, but occasionally a white spot was discernible at the extremities of the angular MnO-rich inclusions (Fig. 5*a*, the same inclusion as in Fig. 1*b*).

Ingot K—No reaction.

Ingot L—All the light-grey round and hemispherical particles within the peripheral annulus of the multiphased inclusions were whitened (Figs. 5*b* and *c*), confirming them as sulphides. Similarly, the light-grey particles in the single-phase matrix were also whitened (Fig. 5*d*), but the two-phase inclusions showing no light-grey particles were unattacked (Fig. 5*e*).

In Figs. 5*b*, *c*, and *d* the same inclusions are shown as in Figs. 3*a*, *b*, and *c*.

It was concluded that this test will positively identify sulphide inclusions, even when they are closely associated with oxides.

Application of 10% Nitric Acid in Alcohol

The time of etching was 10 sec. which rather over-etched the metallic part of the specimen. Inclusions in all three samples were found to have suffered negligible attack from this solution, but appeared in heightened relief, sometimes with a dark outline caused by attack at the metal/inclusion interface.

Application of 10% Chromic Acid in Water

Ingot H—Usually no effect except that the MnO-rich inclusions appeared slightly more translucent, perhaps because the MnO_2 layer was dissolved.

Ingot K—Usually no effect, but some inclusions appeared to have fallen out because of attack on the metal by the etchant.

Ingot L—The acid vigorously attacked the light-grey sulphide particles, and often attacked, more or less completely, the peripheral annulus which contained the small sulphides (Figs. 6*a* and *b*). This test, however, did not seem to be infallible, as it occasionally left unattacked some particles, apparently sulphides, which were rather finely dispersed within the oxide particle (Fig. 6*c*).

The conclusion drawn from this etching procedure is that sulphides may be attacked by cold 10% chromic acid in water. Whiteley[7] found that in the cold solution only MnS was attacked but that in the hot solution FeS was also attacked.

Application of 5% Alcoholic Hydrochloric Acid Solution

Ingot H—Some attack, occasionally heavy, occurred on the MnO-rich inclusions, some of which appeared to have fallen out (Fig. 7*a*).

Ingot K—All the inclusions were completely attacked and dissolved out (Fig. 7*b*).

Ingot L—All the inclusions were attacked to a greater or lesser extent, some being entirely removed, whilst others were only darkened or roughened.

From this etching procedure it was concluded that 5% alcoholic hydrochloric acid attacked inclusions consisting of solid solutions of (Mn, Fe)O over a wide range of values of the MnO/FeO ratio.

DISCUSSION OF TYPES OF INCLUSIONS PRESENT

Ingot *H*

The inclusions that are rich in MnO have a freezing point above that of the metal, and consequently form either angular idiomorphic or dendritic forms. The more translucent 'drops' often attached to the corners of some of the angular inclusions may be either the first beginnings of the dendritic structure which, being shallow, appear more translucent ; or lower melting point glassy silicates. Any large inclusions containing opaque particles are possibly extraneous in origin.

Ingot *K*

The inclusions are mainly rich in FeO and so the surrounding metal solidifies first ; this makes the inclusion globular, possibly an effect of the surface tension.

The presence of small particles of iron often seen within the inclusion may be caused by :

(i) An entrapment of iron globules within the inclusion, although this is not very probable.

(ii) A breakdown of the FeO on cooling to the entectoid of Fe and Fe_3O_4,

$$4FeO = Fe + Fe_3O_4.$$

This would liberate iron and also form Fe_3O_4 of which, however, none was observed.

(iii) Rejection of the iron from solid solution in the wüstite during cooling.

(iv) A separation of liquid Fe-rich solution from liquid oxide solution.

The idiomorphic crystals occasionally seen within the FeO-rich particles may come from extraneous sources or may be caused by an alteration in the composition of the molten inclusion on solidification of the metal, *i.e.* an enrichment in FeO.

Ingot *L*

The presence of the darker phase within a globule of the lighter phase may be explained by the mechanism suggested for ingot *K*, namely, that the inner particle is richer in MnO, and the outer particle richer in FeO.

The FeO-rich part, being the more fluid, also contains the sulphide (MnS) which separates out as globules in the peripheral annulus. The lack of sulphide in the inner particle is significant. Where there is no inner particle the whole inclusion seems to be FeO-rich.

Acknowledgments

The authors wish to thank Mr. F. H. Saniter (Director of Research, The United Steel Companies, Ltd.,) for permission to publish this paper, and they acknowledge the criticism and assistance received from the members of the Solid Steel Study Group.

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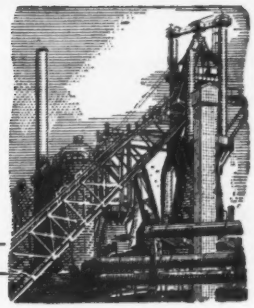
IRON AND STEELWORKS ENGINEERING

THE IRON AND STEEL ENGINEERS GROUP



DESCRIPTION OF NEW PLANT

The W1400 Walking Dragline at Corby

IN THE 1950 Presidential Address to The Iron and Steel Institute, J. R. Menzies-Wilson referred* briefly to the large walking dragline that was then under construction for use in the Priors Hall ironstone quarries of Stewarts and Lloyds, Ltd., Corby. He mentioned that an extension of operations in the quarries meant that greater depths of overburden had to be removed, involving special problems in the handling and disposal of the spoil.

The new dragline was designed for this purpose to be capable of handling up to 100 ft. of overburden. The conditions under which the machine has to operate, and the method of operation, are shown diagrammatically in Fig. 1. The dumping radius had to be such that the dragline could dig and dispose of the spoil at a distance, in relation to the depth of

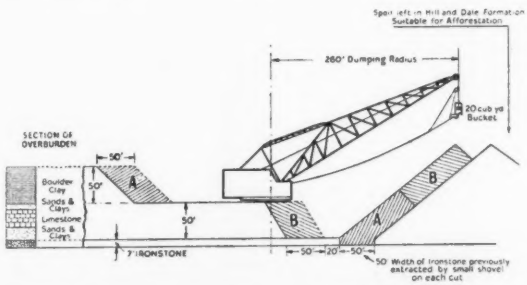


Fig. 1—Operating conditions of the W1400 dragline

excavation, sufficient to provide working room for the small excavator to remove the ironstone. This condition decided the length of the jib, which is 282 ft. long, giving a capacity reach of 20 cu. yd. at 260 ft. radius. Designs for the dragline were submitted by Ransomes and Rapier, Ltd., and the order was placed with them in 1947. The design for the jib and **A** frames was evolved by Tubewrights, Ltd., a subsidiary of Stewarts and Lloyds, Ltd., in collaboration with Ransomes and Rapier, Ltd., who had overall responsibility for the entire machine.

When the machine was finally completed, in July 1951, it walked itself out of the pit in which it had been constructed to the quarry face. It is estimated that the operation of the machine over 33 years will exhaust the ironstone available at the quarries under 100 ft. of overburden.

In the following brief description of the dragline the general construction and the mechanical and electrical features have been dealt with separately for convenience, although, of course, in a machine of this nature each is an integral part of the other.

GENERAL CONSTRUCTION

The machine comprises the base structure resting on the soil, the revolving superstructure and cab, the jib, and the walking gear. The whole weighs 1650 tons. Apart from the jib, cabin, and various castings, the general construction was of mild-steel plate and rolled sections, liberal use being made of deep broad-flanged beams in the girder construction.

The Base Structure

This was built up of 16 radial girders instead of the more usual cellular construction, and is 48 ft. dia., 4 ft. high presenting a bearing area of 1809 sq. ft. It weighs 227 tons. The radial girders are connected to the fabricated centre-post weldment to provide full continuity (*see* Fig. 2). A circular outside girder supports rollers on which the whole superstructure revolves. Between the centre post and the support rollers is the 33-ft. dia. rotate rack with which the rotate pinions engage. A heavy hook-rail, machined from a solid mild-steel bar, is attached below the upper flange of the circumferential girder. Hooks on the superstructure lift the weight of the base on this rail during the walking operation.

Revolving Superstructure

The main structure supporting the jib and housing the machinery is a cantilever unit supported at one

* J. R. Menzies-Wilson, *Journal of The Iron and Steel Institute*, 1950, vol. 165, pp. 129-137.

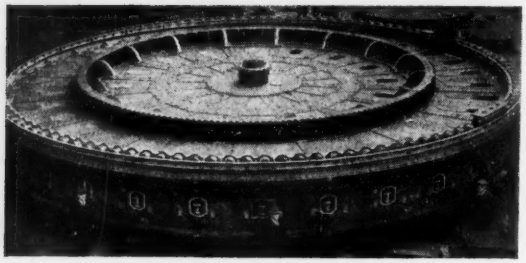


Fig. 2—Base assembly, showing supporting rollers and rotate rack

end on the live rollers. Four main longitudinal girders 14 ft. deep are connected at the forward end to a circular girder of the same depth. A 17-ft. deep transverse girder at the rear end and intermediate full-depth girders, with the whole plated over top and bottom, provide a stiff structure that can withstand the heavy external and local machinery loads with neglible deflection.

At all points of heavy concentrated load, such as at the jib feet and the front **A** frame supports, massive weldments and doubling plates are incorporated in the structure to distribute the loads as widely as possible. A deep transverse bridge girder, forming an integral part of the superstructure, distributes the weight of the structure through the longitudinal girders to the walking axles. Two-thirds of the weight of the base is carried from this transverse girder during the walking operation.

The machinery house and cabins are constructed of angle framework covered with flanged ⅛-in. thick plates, and stairways and platforms give easy access. The operator's cabins are arranged one on each side of the structure, separate from the machinery house, and placed well forward to provide a clear view down the quarry face. The machine can be controlled from either cabin according to the direction of operation along the face of the quarry. An enclosed glazed gallery extends around the front circular girder, in which time-study and instrument recording rooms are located.

Walking Gear

This is based on the Cameron-Heath patent designs as used on all Rapier walking draglines.

Two hollow forgings 2 ft. 11 in. dia. and 13 ft. 11 in. long, weighing 7·76 tons each, are fabricated into the outer ends of the bridge girder to form the axles for the walking eccentrics (*see* Fig. 3). The latter are bronze bushed to rotate about the outside of the axles. The inner rotating shafts are 20 in. dia., each weighing 16½ tons. The squared outer ends are fitted to recesses machined in the eccentric bosses, whilst the inner ends are also squared to receive the main driving gears. The shafts are supported, cantilever fashion, by journals mounted on the inner longitudinal girders. The walking eccentrics and the walking legs are large weldments, and heavy cast steel components are placed at the eccentric boss, which forms the inner race of the roller bearing on the axle, and at the lower ends of the legs, which carry split bronze spherical bearings for the universal ball connection to the shoe axle.

The upper ends of the legs are connected by links to stub axles formed by projections from the top member of the transverse bridge girder.

Shoes

The walking shoes, constructed of plate and broad-flanged beams, are 48 ft. long × 9 ft. 6 in. wide, each weighing 56 tons. They provide a total bearing area of 890 sq. ft.

Jib and A Frames

The working jib, suspension member, and supporting **A** frames are constructed throughout of welded tubular members of high-tensile Cr–Mo fine-grain steel. The tubes vary in diameter from 1¼ in. to 16 in. The usual box-shaped jib built from standard rolled sections was not possible unless complex compound sections were to be used for the compression members, and although there was no previous experience of fabricating tubular jibs longer than 113 ft., it was finally decided to construct a triangulated tubular cantilever jib. The general construction is shown in Fig. 4. The two main compression members and the tension boom are twin tubes with distance pieces welded in. The compression members run from the jib head to heel pieces at the superstructure and are suitably braced by latticed tubular frames. They taper from 16 in. dia. under the apex to 10 in. at the head and 15 in. at the heel. The tension member tapers from 5½ in. at the head to 15 in. at the apex where it divides into two tubes connected to the heel pieces.

A twin-tube system was also adopted for the two **A** frames. The legs are built into the machine housing whilst the top forms an anchorage for the suspension member that holds up the jib. This member is a rigid box-beam arrangement of four 10-in. tubes and is

Fig. 3—View of walking leg and shoe during erection. A torque bar is visible under the cabin at the left-hand side

connected to the **A** frames by a link system. This allows adjustment of the working angle of the jib and also relieves the jib tension member of any compression strain caused by a sudden release of load from the jib. Catwalks, built up of square tube sections, are provided over the full length of the jib and they also serve inspection platforms at the top of the **A** frames, at the apex, and at intermediate points where banks of floodlights are fixed.

The weight of the jib alone is 94 tons, and with the catwalk, suspension members, and other accessories, 126½ tons.

Material—The tubes are of three types :

(*a*) For main compression and tension members
(*b*) For **A** frame and subsidiary bracing members
(*c*) For lattice bracing members.

Type (*a*) tubes are seamless and were rolled in the Pilger mill at Stewarts and Lloyd's Bromford works, cold drawn at the Chesterfield Tube Company's works, and then normalized at the Bromford works.

Type (*b*) tubes are hot-finished seamless tubes made by the Pilger process at Bromford.

The lighter tubes (*c*) were made at Corby by the continuous weld process from Bessemer steel.

At the tube junctions and at the points of loading, stub tubes are welded to heavy steel forgings, the main tubular members then being welded to the stubs during erection. The 17 forgings for the jib and **A** frames were made at the Parkhead Steel Works of William Beardmore and Co., Ltd., from ingots cast at the Bilston and Corby works of Stewarts and Lloyds. The forged blocks were then oxyacetylene cut to shape at the Clyde works of Stewarts and Lloyds, special cutting nozzles being designed by the British Oxygen Co., Ltd., for cutting up to 48-in. thicknesses of steel. After normalizing, the forgings were finally machined to the finished sizes.

Welding—The main compression and tension members were assembled in 40-ft. lengths in the works and butt welded at site. Backing rings were inserted at the butt welds and reinforcing plates were provided at the intersection points of multiple tubes. All work was preheated to 160° C., and finished welds were allowed to cool under asbestos blankets. A weld once started was carried through to completion to avoid loss of heat. High-tensile steel electrodes of the BEAMA/IOW/E110P type were employed throughout.

Every weld was examined after completion and some were tested magnetically. The 32 welds in the tension members of the suspension link were examined radiographically ; 29 were sound, and although the remaining three showed only indistinct markings they were cut out and rewelded.

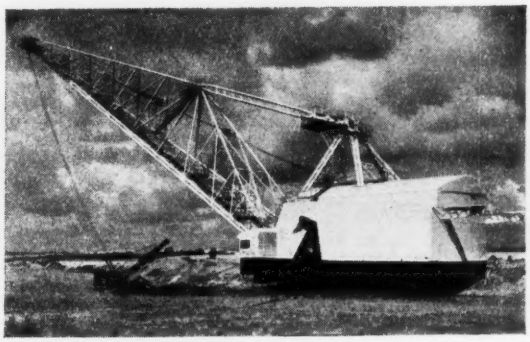


Fig. 4—General view of the dragline. The cantilever extension of the 25-ton service crane is shown at the rear of the cabin

MECHANICAL FEATURES

The main mechanical operations are slewing, hoisting and dragging, and walking : the prominent mechanical details of each motion will be dealt with in that order.

Slewing

The live ring between base and superstructure consists of 120 tapered rollers of 10-in. dia., grouped into small cage units of 4 rollers to facilitate renewal. The cast-steel rotate rack is in 16 segments and the 208 teeth are cut to a 6-in. circular pitch 19 in. deep on a pitch circle of 33 ft. 1⅓ in. dia. The segments are connected to the base by 196 bolts 2 in. dia. There are two rotate units housed between decks on either side, and forward of, the centre of rotation. Each unit is totally enclosed in oil-tight fabricated boxes and each is driven by a vertical 225-b.h.p. continuously rated motor. The main rotate pinions are forged integral with the driving shafts, and provide a total gear ratio of 775 : 1. Under no load the superstructure turns at a speed of 1·225 revs./min., equivalent to 2000 ft./min. at the jib head.

Hoisting and Dragging

The two 7-in. drag ropes pass from the bucket through fairleads on the main deck to the winding drum in the cab. The fairleads of orthodox construction are two units of similar design mounted in a single frame standing directly over the main circular girder. Two vertical and two horizontal pulleys in each unit are of high-tensile cast steel mounted on hard bronze bushes, the vertical bushes being protected by bellows-type seals with cast-steel covers. The guide cheeks are smaller than usual, the wear being minimized by mounting them in balanced arms carried on the lower vertical pulley pins, thus allowing them to operate at a greater distance from the swivel pins than is usual. The winding drum is 5 ft. in dia. and is grooved right and left hand to the centre to carry two ropes.

The two hoist ropes are 6½ in. in circumference and pass from the bucket to pulleys at the head of the jib and over jockey pulleys down the centre of the jib to the winding drum, which is also 5 ft. in dia. The hoist and drag units are of identical design except for the drum grooving. The units are self-contained, mounted on the top deck of the superstructure, and a balanced drive is provided from four 225-b.h.p. motors. No operating brakes or clutches are incorporated but a disc-type holding brake is provided at each motor. The total gear ratio is 29·2 : 1 through machine-cut double helical first reductions, where the pinions are driven through flexible couplings and are placed diametrically opposite on the gear wheels. The second reduction consists of machine-cut straight gears and the pinions are machine cut from the solid

shaft, again placed diametrically opposite to engage the main drum wheel.

The maximum (stalled) pull on the ropes is 100 tons, and the no-load speed is 513 ft./min. At 75 tons the speed is 290 ft./min.

The jib hoist unit is a self-contained winch mounted on the main deck at the forward end of the house. It is fitted with a 50-h.p. slip-ring crane-type motor with a drum-type controller. Special brake gear provides a slow speed control and the drive is through worm and spur gearing. The drum is 4 ft. 6 in. in dia. and 10 parts of 6-in. circumference rope are used. When the boom is in position, the links between the main suspension member and the **A** frames relieve the hoist unit and ropes from tension.

Walking

At the inner ends of the walking shafts, already mentioned, are fixed two driving wheels 12 ft. in dia. and 14 in. wide, weighing ten tons each. Two pinions engage with each wheel at opposite sides so that the shaft is not subjected to bending moments from the tooth loading. The four walking motors, each of 225 b.h.p., are connected in the same way as for the hoist and drag motions to ensure shared tooth loads and a balanced drive. The links at the upper ends of the walking legs are designed to constrain the movement of the upper end pins to an arc during a revolution of the eccentric. This forces the other end—the shoe axle—to describe an elliptical path with the major axis of about 7 ft. almost horizontal.

A torque device, invented by Cameron and Baliki, has been incorporated to provide self-adjustment of the walking shoes in the case of misalignment during operation over uneven ground. Preloaded torque tubes fixed horizontally to the sides of the superstructure are connected by levers to universal joints at the rear ends of the shoes. The rotation of a shoe about the vertical axis of the main universal joint at the centre of the shoe alters the torque in the tubes, and when the shoe is next raised from the ground it is forced back to its correct position, parallel to the main structure.

ELECTRICAL EQUIPMENT

The power to the dragline is supplied through two 4-core flexible trailing cables at 6·6 kV., which enter the base structure through two oval openings and join at the centre post. The power is then taken through an air-insulated collector ring on the centre post to two control cubicles in the superstructure. At each cubicle it divides through separate isolating switches, the main supply being taken to an auto-transformer starter for the synchronous motor driving one of the motor-generator sets, and the other supply to a 222-kVA., 3-phase, 6600/440-V. transformer for the auxiliary motors or a 50-kVA., 3-phase, 6600/110-V. lighting transformer. Each main motor-generator set is made up of four units, a 1500-kVA. synchronous motor, a 400-kW. hoist generator, a 400-kW. drag generator, and a 200-kW. slew generator. The rotating portion of the set is supported on five pedestal ring-lubricated journal bearings, a single row self-aligning ball bearing at one end acting as a thrust bearing. The separate shafts of the four motors are connected by three solid couplings.

The main motors have Ward Leonard control obtained by varying the separate excitation on the generator fields in conjunction with Amplidyne generators. The excitation supplies at 125 V. for the D.C. motor and generators, and at 45 V. for the synchronous motor field, are taken from one of two motor-driven exciter sets, the other being a standby. This set also includes an Amplidyne generator to maintain the power factor of the synchronous motor at unity. A separate Amplidyne is provided for the control of the hoist, drag, and slew generators.

The four hoist and drag motors are connected in pairs across each of the hoist and drag generators. The motors are shunt wound and are separately excited from a 125-V. excitation supply. The two vertical motors supplying the slewing motion are constructed in the same manner. The supply for the four walking motors is taken from the two drag generators. A motor-operated multi-pole switch is provided for changing over the armature and field connections.

Control is effected from one of two similar consoles, set in the two cabins at each side of the forward superstructure, each comprising three cam-finger-type master controllers for the hoist, drag, and slew generators (*see* Fig. 5). Push buttons and switches for the auxiliary and lighting circuits are set in panels at the sides of the consoles. The contactors and relays for the generator and motor fields are grouped in totally enclosed cubicles, and the resistances are enclosed in protected ventilated cases. All rotating machines and switchgear are protected by heaters from condensation in damp weather, and the main driving motors are force ventilated by individual motor-driven blower units.

AUXILIARY EQUIPMENT

Service Cranes

The main machinery house is provided with a 25-ton electric overhead crane with two 12½-ton grabs. The gantries run from the front of the house to a cantilever extension beyond the rear of the house to deal with loads from the ground (*see* Fig. 4). The crane is power driven on all motions, being provided with two

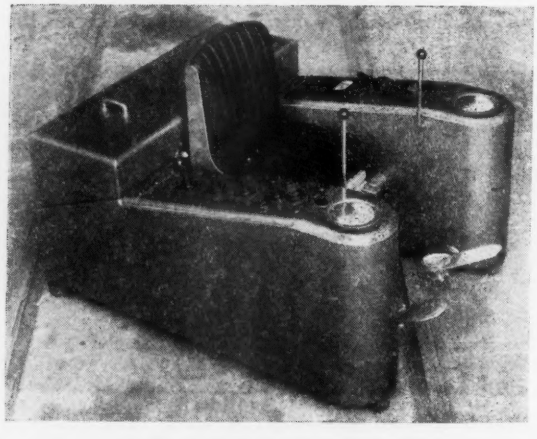


Fig. 5—Operator's console

10-h.p., one 5-h.p., and two 2-h.p. motors supplied from the 125-V. exciter sets. The top part of the rear end of the superstructure moves with the crane, and the lower portion can be removed by means of the crane to allow complete access to all machinery.

A crane gantry with an electric pulley block is also fitted over the fairleads for maintenance purposes.

Ventilation

A complete filtering and fan equipment is provided capable of supplying 60,000 cu. ft./min. of filtered air for cooling of electrical equipment and for maintaining a pressure above atmospheric in the machinery house to exclude dust. Five fans driven by four 7½-h.p. and one 8-h.p. squirrel-cage motors draw air through two groups of 3-bank rotating self-cleaning filters.

Lubrication

Two separate oil-spray equipments are provided for lubricating the totally enclosed main rotating units. An audible warning is given in the driver's cabin if the pressure falls below normal. Other journal bearings are fed from an automatic metering system electrically driven and operated by a time switch, so that every point receives the correct amount of lubricant at regular intervals. A change-over system ensures that while the walking mechanism is out of action it will not be over lubricated.

Floodlighting and Communication

Illumination is provided by a floodlighting system on the jib, using ten 1000-W. and three 500-W. projectors. This provides sufficient overall illumination for the dragline to be operated as easily by night as by day. The interior lighting on the upper deck of the machinery house consists of twelve 300-W. wall lanterns and four 300-W. reflectors on the roof. Bulkhead lighting fittings are installed at convenient points between decks.

A complete 2-way system of telephonic communication is provided between the driver's cab and various stragetic points in the machinery house so that timely warning of breakdown or failure may be given. A hooter gives warning that the walking motion is to take place.

ERECTION

To allow the jib to be constructed in an almost horizontal position the base and superstructure were assembled in a pit 20 ft. deep. All the main components were assembled and fitted at the works and were then dismantled for dispatch and final assembly at the site. The jib was built up on carefully levelled concrete pads, whilst the **A** frames and suspension members were fabricated nearby. After the latter had been mounted on the machine, the jib was moved back so that the heel pieces entered the sockets on the deck of the machine, and it was then raised by derrick to its final working position and connected to the suspension member.

A team of scrapers then removed the earth from one end of the working pit to form a ramp, up which the machine walked to the quarries.

RECOMMENDATIONS TO AUTHORS

Submission of Papers

Authors who intend to submit papers for publication in the *Journal* are reminded that space is severely limited. Delay in publication can be avoided only by publishing more papers of shorter length.

A style of writing which is concise and yet clear in expression will be read with greater ease and understanding than one that is verbose and vague. In particular, the repetition of data in tables, figures, and text should be avoided.

Wherever possible the Editor will shorten a lengthy paper, but it is obviously in the interest of the author that he should consider any possible condensation before submitting his manuscript.

Attention is drawn to the "General Notes on the Preparation of Scientific Papers," published in 1950 for the Royal Society by the Cambridge University Press (Price 2*s.* 6*d.*).

Letters to the Editor

The ever increasing demands on the limited space of the *Journal* have led the Publication Committee to suggest that a section should be devoted to "Letters to the Editor." It is intended that these should be brief notes, describing some new method, apparatus, or important finding that may be of general interest, which do not require the preparation of a full paper or report.

They are intended to replace, rather than to augment, the short papers (2–3 pp.) that appear frequently in the *Journal*, and so to release space for presenting the results of more detailed investigations.

Authors submitting such notes for publication should clearly indicate that they are "Letters to the Editor."

Preparation of Manuscripts

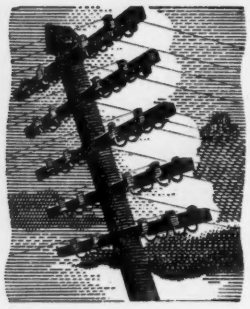
The work of the editorial staff will be greatly assisted if authors follow the requirements of the Publication Committee set out below. The top copy of the manuscript should be submitted; a second copy, if available, is useful, for delay may be avoided when the paper is refereed.

(1) Manuscripts should be typed, in double spacing, on one side of the paper. Duplicated reports, unless printed on non-absorbent paper, cannot be accepted. Mathematical expressions, Greek or other symbols, should be hand written, with ample allowance between typescript matter.

(2) Diagrams should be drawn in black Indian ink on tracing cloth, Bristol board, or stout drawing paper, and generally should be at least twice the size of the final reproduction, which will usually be at column width (3⅛ in.) or page width (6½ in.). All lettering should be written in pencil, either on the original drawing or preferably on a separate print (if a print is possible) or rough sketch.

(3) Photographs (unmounted) should be printed on glossy bromide paper to give sharp contrast. It is helpful to the Editor if authors indicate on the back of the print the important area of the photograph which is to be reproduced, as this enables the block to be made at the smallest size without unnecessary reduction. All diagrams and photographs should be numbered and should be accompanied by a list of captions attached to the manuscript.

(4) Tabular matter should be kept to a minimum and should not repeat data already shown graphically.



NEWS

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

President-Elect

Capt. H. LEIGHTON DAVIES, C.B.E., J.P., has been nominated by the Council for election as President for the year 1952–53, to take office at the Annual General Meeting in April.

Capt. Davies is Assistant Managing Director of The Steel Company of Wales, Ltd. He has been a Member of the Institute since 1918, and a Member of Council since 1932. He was elected a Vice-President in 1943.

Andrew Carnegie Research Fund

Mr. J. BURKE (Liverpool University) has been awarded a second grant from the Andrew Carnegie Research Fund in aid of his research on "The Decomposition of the Carbide Constituent in High Purity Cast Irons."

The following awards have also been made :

Mr. M. J. OLNEY (Cambridge University) for work on the use of a reflecting microscope for high-temperature metallography.

Mr. A. SHEETON (Imperial College of Science and Technology) for research on the measurement of Poisson's ratio in the elastic range of various metallic materials, and also in the plastic state at various degrees of work-hardening.

Abbreviations Used by the Abstracting Service

A list of the periodicals examined by the abstracting service is given on p. 59 of this issue of the *Journal*. To save space abbreviations will in future be used for the title of the periodical from which abstracts are published. The abbreviations to be used are given in bold-face type in the list of periodicals. In the published abstracts the abbreviated titles will be followed by the date, volume number (in bold-face type), part number if any, and page numbers.

Special Report on Ingot Surface Defects

A further addition has been made to the series of Special Reports published from time to time by the Institute. It is a report on "*Surface Defects in Ingots and Their Products*" prepared by a Sub-Committee of the Steelmaking Division of the British Iron and Steel Research Association.

Its object is to reduce the confusion of terms and to promote a better understanding of the nature and causes of defects occurring in ingots and their products. This is done by illustrating and providing recommended definitions for the commonly occurring defects.

The report is divided into three sections : one dealing with defects present in the ingot ; one dealing with defects in finished and semi-finished products arising from defects in the ingots ; and the third illustrating defects occurring during processing.

The 105 half-tone representative illustrations of defects and the text are printed on 52 pages of art paper and the whole is bound in cloth with stiff board covers. The report, No. 44 in the series, is available from the offices of the Institute at 25*s*. per copy, post free (15*s*. to Members).

NEWS OF MEMBERS

▶ Mr. GEORGE BAKER, Chairman, and Mr. EDWARD BAKER, Director, have retired from Messrs. John Baker and Bessemer Ltd., Rotherham. The new Chairman is Mr. S. E. BAKER. Mr. HENRY BAKER, Mr. BERNARD BAKER, and Mr. R. C. BAKER have been appointed to the Board.

▶ Mr. M. W. BARLOW has resigned from his position as Sales Manager of British Electro Metallurgical Co., Ltd., to become Manager of the newly established Ferro Alloy Division of Foundry Services, Ltd., Birmingham.

▶ Professor P. G. BASTIEN, Scientific Director of Schneider and Co., has been elected President of the International Committee on Testing Cast Iron.

▶ Professor PAUL A. BECK has transferred from the University of Notre Dame, Indiana, to the College of Engineering, University of Illinois, U.S.A.

▶ Mr. J. BLACKBURN is now Chief Metallurgist and Assistant Works Manager of the Osborn Foundry and Engineering Co., Ltd., Sheffield. He took up his new position about a year ago.

▶ Mr. R. P. BRADSHAW has left the University of Cambridge to take up an appointment with Associated Lead Manufacturers, Ltd., Chester.

▶ Dr. A. T. CHURCHMAN has resigned from a Research Fellowship at Birmingham University to take up an appointment as Research Metallurgist with Associated Electrical Industries, Ltd., Aldermaston, Berks.

▶ Mr. L. H. COPE has resigned from his position as Research Metallurgist with Stewarts and Lloyds Ltd., Corby, to take up an appointment as Lecturer in Metallurgy at Corby Technical College.

▶ Mr. J. W. DONALDSON is now at Macalder-Nyanza Mines, Ltd., Kisumu, Kenya Colony.

▶ Mr. D. R. GODDARD has resigned his position as Technical Manager of British American Research Ltd., Wishaw, Lanarkshire.

▶ Mr. C. C. HANSON has resigned his position with the Industrial Research Laboratories, Birmingham, and has been appointed Metallurgist and Technical Adviser to Messrs. High Grade Steels, Ltd., Birmingham. He has been elected an Associate of the Institution of Metallurgists.

▶ Mr. FRANK HARGREAVES has been appointed Regional Works Metallurgist with British Railways, Southern Region (Brighton).

▶ Mr. P. L. JACKSON, formerly of the Buick Motor Co., Flint, Michigan, has taken up an appointment as Research Engineer in the Scientific Laboratory of the Ford Motor Company, Michigan, U.S.A.

▶ Mr. W. H. LEWIS has left the British Rollmakers Corporation, Ltd., Wolverhampton, and is now with the Midland Rollmakers Ltd., Crewe.
▶ Dr. G. D. MCADAM has left Messrs. Hepworth and Grandage Ltd., Bradford.
▶ Mr. J. H. OSBORN has been appointed a Director of Samuel Osborn and Co., Ltd., Sheffield.
▶ Mr. J. R. M. RICHARDS has left Austria to take up an appointment with Stewarts and Lloyds Ltd.
▶ Mr. K. C. SHARP has joined the Blast-Furnace Department of the Margam Works, The Steel Company of Wales Ltd., Port Talbot.
▶ Mr. E. V. TULL has left the Military College of Science, Shrivenham, to undertake post-graduate research at University College, Swansea.
▶ Mr. J. R. WILES is now working in Brakpan, Transvaal, S.A., for A. C. Wickman Ltd.

Obituary

Mr. J. D. BRUNTON, O.B.E., formerly of Messrs. Bruntons (Musselburgh) Ltd., Scotland, on 5th July, 1951.

Mr. T. S. WILKINSON, formerly Governing Director of G. W. Wilkinson and Sons Ltd., Leeds, on 24th October, 1951.

CONTRIBUTORS TO THE JOURNAL

W. Ruff, Dr. Ing.—Working at the Istituto Sperimentale dei Metalli Leggeri, Novara, Italy. Dr. Ruff was born in 1906 at Danzig. He graduated as an engineer from the University of Breslau in 1930 and in 1932 he was awarded a doctorate of the University of Braunschweig for his work on the graphitization of cast iron. He spent two years in the United States under a grant from the Dr. Duisberg Foundation Committee of the I.G. Farbenindustries. In 1935 Dr. Ruff started research work on the fluidity of iron and steel, assisted by a grant from the Carnegie Fund of The Iron and Steel Institute. He was awarded the Carnegie Gold Medal in 1936.

W. Ruff

During the last war and the subsequent Russian occupation, Dr. Ruff continued his research work. In 1948, at the invitation of Professor Panseri, he went to Italy, and is now working at the Istituto Sperimentale dei Metalli Leggeri.

J. O. Ward, A.Met., A.I.M.—A member of the research staff of Hadfields, Ltd., Sheffield. From 1940 to 1947 Mr. Ward was a member of the research staff of Messrs. Wm. Jessop and Sons, Ltd. Then he joined his present firm, working first in the Physics Section and then on high temperature alloy research. He was awarded an Associateship in Metallurgy by the University of Sheffield in 1948, and was elected an Associate of the Institution of Metallurgists in the same year.

S. G. Clarke, Ph.D., D.Sc., A.R.I.C.—Head of the Corrosion Section of the Metallurgy Branch of the Armament Research Establishment, Woolwich. Dr. Clarke graduated from London University in 1923, with 1st class honours in chemistry. He subsequently studied metallurgy and carried out chemical and electrochemical research. He joined his present Establishment (at that time The Research Department, Woolwich) in 1925.

S. G. Clarke

E. E. Longhurst

Dr. Clarke is Honorary Secretary of the Corrosion Group of the Society of Chemical Industry.

E. E. Longhurst, Ph.D., B.Sc.—Metallurgy Branch of the Armament Research Establishment, Woolwich. Dr. Longhurst obtained the degree of B.Sc. (Hons. Chem.) in 1942, and was awarded a Ph.D. degree in electrochemistry in 1949. He joined the Armament Research Establishment in 1938, and is studying the corrosion and protection of metals, under the direction of Dr. S. G. Clarke.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

4th Junior Blast-Furnace Conference

The Fourth Junior Blast-Furnace Conference was held at Ashorne Hill, under the Chairmanship of Mr. G. H. Johnson (Deputy Chairman of the Iron Making Divisional Panel), on October 8th and 9th, 1951: 56 Members of status up to and including Assistant Blast-Furnace Manager, attended.

Mr. G. D. Elliot (Appleby-Frodingham Steel Co.) in presenting a paper on "Interesting Experiences in Blast-Furnace Management" drew on his long experience to describe unusual occurrences on furnace plants; he particularly stressed the need for the accumulated experience of the older foremen and workers at furnaces, gained in times when troubles were more frequent, to be passed on to the present generation, particularly in connection with the prevention of accidents, some of which seemed to appear with almost cyclic regularity.

The paper by H. S. Ayres (Appleby-Frodingham Steel Co.) on "Practice Used in Blowing-In and Blowing-Out Blast-Furnaces" aroused discussion on the relative merits of the Fowler method and a new method based on an inert charge of pebbles, for blowing-out.

Mr. W. Eland (Messrs. Richard Thomas and Baldwins, Ltd.) presented a paper on "The Manufacture of Coke in Relation to its Use in the Blast-Furnace," which described the blending of coals to produce suitable blast-furnace coke. He appealed for a better balance between the coals available and the coke requirements, on a regional basis.

19th Blast-Furnace Conference

Mr. G. H. Johnson also took the Chair at the Nineteenth Blast-Furnace Conference held at the Priestley Hall, Leeds, on 31st October and 1st November, 1951: 80 Members attended. The principal item discussed was "The Assessment of Blast-Furnace Performance," and papers were presented by R. P. Towndrow (Chairman of the Blast-Furnace Practice Committee) and S. Klemantaski (B.I.S.R.A.). The purely statistical and the partly empirical approaches to the problem were put forward, and created an excellent discussion. The need for much

further work, specialized on limited ranges of burden conditions and practice, was emphasized.

In the session on "Taphole Clays and Aspects of Taphole Practice," a research paper was presented by H. M. Richardson (B.C.R.A.) and D. L. C. Plummer (formerly of B.I.S.R.A.), and practical papers by W. Banks (Colvilles, Ltd.) and D. W. E. Lloyd (Ford Motor Co., Ltd.). It was generally concluded that successful taphole practice depended less on the properties of the clays than on the mechanical aspects of the guns used and the entry of the clay into the hole.

INSTITUTE OF METALS

Non-Destructive Testing of Metals

Under this title the Institute has published, in the Monograph and Report Series (No. 10), a book by Dr. R. F. Hanstock, Chief Physicist to High Duty Alloys, Ltd. The publication is a comprehensive survey of the various methods that are available for the non-destructive testing of metals, ranging from liquid-penetration methods of crack detection to the use of X-ray diffraction for the determination of grain size and orientation, and for the measurement of internal stresses. Special attention is devoted to damping-capacity measurement as a means of non-destructive testing. The properties that may be assessed by non-destructive means, the various methods applicable in each case, and brief comments on their suitability and limitations, are given in tabular form in an Appendix.

NEWS OF SCIENCE AND INDUSTRY

Summer School on Welding Design and Engineering

The British Welding Research Association has decided to hold another Summer School in 1952. This will be held at Ashorne Hill from Wednesday, 16th July, until Friday, 25th July. The School will be divided into two parts—the first part from Wednesday, 16th July, until Sunday, 20th July, being for those concerned with the purely practical aspects of welding, and the second part from 20th July, until Friday, 25th July, being for those concerned with design, inspection, and manufacturing problems.

Saving Scarce Materials

Since the shortage of materials has been considerably increased by the rearmament programme and by the fact that world production of basic raw materials has not, in recent years, been increased at the same rate as world production of goods, a specialist group visited the United States in June and July, 1951, under the auspices of the Anglo-American Council on Productivity, to study measures for economizing in scarce materials. Their report entitled "Saving Scarce Materials," has now been issued. It deals with the advances made in the U.S.A. in the use of low-alloy and plain carbon steels, particularly in the engineering and allied industries. It is suggested that a considerable saving of scarce ferro-alloys and alloying elements in Britain would result from the adoption of similar techniques.

Copies of the Report may be obtained from the Anglo-American Council on Productivity, 21 Tothill Street London, S.W.1 (price 2*s*. post free).

Super-Refractory Materials

The Carborundum Company Ltd., Manchester, have recently completed a new instructional colour film which is believed to be unique in the annals of industrial cinematography. It deals with the wide applications of super-refractory materials, including their use in the Royal Mint, and runs for approximately 45 minutes.

DIARY

9th Jan.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—"*Developments in Deep-drawing of Steel Sheets*," by W. H. R. Bird—Central Library, Swansea, 6.30 P.M.

9th Jan.—MANCHESTER METALLURGICAL SOCIETY—"*Cast Iron*," by J. E. Hurst—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

9th Jan.—PURCHASING OFFICERS' ASSOCIATION—Discussion on Steel Authorization by Ministry of Supply Official—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.30 P.M.

10th Jan.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*High Temperature Alloys*," by E. H. Bucknall—Station Hotel, Dudley, 7.30 P.M.

11th Jan.—LIVERPOOL METALLURGICAL SOCIETY—"*The Use of Radioactive Tracers in Metallurgical Research*," by H. M. Finniston—The Lecture Theatre, Electricity Service Centre, Whitechapel, Liverpool, 7 P.M.

15th Jan.—LINCOLNSHIRE IRON AND STEEL INSTITUTE—"*Aspect of Open-Hearth Practice; Influence on Variability of Materials*," by D. R. G. Davies—Wortley Hotel, Scunthorpe, 7.30 P.M.

15th Jan.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Silica versus Basic Bricks*," by T. R. Lynam—Grand Hotel, Sheffield, 7 P.M.

21st Jan.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Presidential Address—The University Building, St. George's Square, Sheffield, 7.30 P.M.

23rd Jan.—NORTH WALES METALLURGICAL SOCIETY—"*Non-Destructive Testing in Steelworks*," by J. F. Hinsley—County Primary School, Plymouth Street, Shotton, Nr. Chester, 7.15 P.M.

23rd Jan.—MANCHESTER METALLURGICAL SOCIETY—General Discussion on Microscopy with Films, opened by J. D. Hannah—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

25th Jan.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—"*Die Forging*," by J. D. Latta—39 Elmbank Crescent, Glasgow, 6.45 P.M.

29th Jan.—SHEFFIELD METALLURGICAL ASSOCIATION—Résumé of Papers presented at the Chemists' Conference at Ashorne Hill, 1951—Grand Hotel, Sheffield, 7 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the December, 1951, issue of the *Journal*, p. 392).

TRANSLATIONS AVAILABLE

No. 430 (Hungarian). A. B. CHELYUSTKIN and B. A. LEVITANSKIY: "Automatic Control of Various Operations in the Iron and Steel Industry." (*Bányaszati és Kohászati Lapok*, 1950, vol. 5, Dec., pp. 700–704).

No. 431 (German). H. DIERGARTEN: "The Grading of Ball Race Steels by the Inclusion Content." (*Archiv für das Eisenhüttenwesen*, 1936, vol. 10, Nov., pp. 197–204; discussion, pp. 204–210).

CHARGES FOR COPIES OF TRANSLATIONS—The charge for translations is £1 for the first copy and 10*s*. for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUEST—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether they can be prepared for inclusion in the Series.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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LIST OF ABBREVIATIONS USED IN THE REFERENCES TO ABSTRACTS

Acciaio Inossidabile (Milan)
Acero y Energia (Barcelona)
Acid Open Hearth Research Association, **Bull**etin (Pittsburgh)
Aciers Fins et Spéciaux Français (Paris)
Acta Crystallographica (London)
Acta Polytechnica (Stockholm)
Advancement of Science (London)
Aeroplane (London)
Aircraft Engineering (London)
Aircraft Production (London)
Alloy Castings **Bull**etin (New York)
Alloy Metals Review (Widnes)
Alluminio (Milan)
Aluminium (Budapest)
Aluminium (Düsseldorf)
Aluminium Development Association, **Information Bull**etin (London)
American Electroplaters' Society, **Research Reports** (Jenkintown, Pa.)
American Foundryman (Chicago)
American Foundrymen's **Soci**ety, **Preprint** (Chicago)
American Institute of Mining and **Met**allurgical **Engi**neers (New York)
Blast Furnace and **Raw Mat**erials **Committee**
Proceedings Electric Furnace Steel Conference
Proceedings National Open-Hearth Committee
Proceedings Symposia Series
American Iron and **Steel Inst**itute (New York)
Annual Statistical Report
Contributions to the **Met**allurgy of **Steel**
Steel Products Manual
American Journal of Physics (New York)
American Journal of Science (New Haven, Conn.)
American Society for Metals, Preprint (Cleveland, Ohio)
American Society for Testing Materials (Philadelphia)
Preprint
Special Technical Publication
Anais da Academia Brasileira de **Cienc**ias (Rio de Janeiro)
Anais da Associação Química do **Brasil** (Rio de Janeiro)
Anales da la **Asociacion Química Argentina** (Buenos Aires)
Anales de la Real Sociedad Española de **Física y Quím**ica (Madrid)
Anales de **Mec**anica y **Electr**icidad (Madrid)
Analyst (London)
Analytica Chimica **Acta** (New York and Amsterdam)
Analytical Chemistry (Washington)
Annales des Mines (Paris)
Annales de la **Société Sci**entifique de **Bruxelles** (Brussels)
Annual Proceedings of the **Sheet** and **Strip Metal Users Tech**nical **Associ**ation (London)
Annual Report of the **Smithsonian Inst**itution (Washington)
Applied Mechanics **Rev**iews (New York)
Applied Research **Lab**oratories, **Reports** (Glendale, Calif.)
Applied Scientific Research (The Hague)
Archiv für das **Eisenhüttenwesen** (Düsseldorf)
Arkiv för **Fysik** (Stockholm)
Arkiv för **Kemi** (Stockholm)
Arkiv för **Mine**ralogi och **Geol**ogi (Stockholm)
Atomics (London)
Atti della **Accad**emia **Naz**ionale dei **Lincei. Rend**iconti della **Classe** di **Scienze Fisiche, Mat**ematiche e **Nat**urali (Rome)
Australasian Engineer (Sydney)
Australasian Plating and **Finish**ing (Melbourne)
Australian Foundry Trade Journal (Sydney)
Australian Journal of Applied Science (Melbourne)
Australian Journal of Scientific Research (Melbourne)
Automobile Engineer (London)
Avtogennoe Delo (Moscow)

B.H.P. Review (Melbourne)
Ball Bearing Journal (Luton)
Bánsky Obzor (Prague)
Beama Journal (London)
Bell Laboratories Record (New York)
Bell System Technical **Journal** (New York)
Bell Telephone Laboratories Technical **Publication** (New York)
Bell Telephone Magazine (New York)
Berg- und **hüttenmännische Monatsh**efte (Vienna)
Betrieb und **Fertigung** (Vienna)
Bibliographical Bulletin of **Weld**ing (Paris)
Blad for **Bergshandterigens Vänner** (Stockholm)
Blast Furnace and **Steel Plant** (Pittsburgh)
Boletim da **Associação Brasil**eira de **Met**ais (São Paulo)
Boletim da **Associação Quím**ica do **Brasil** (Rio de Janeiro)
Boletim da **Soc**iedade **Geol**ógica de **Portugal** (Oporto)
Boletin de **Inform**acion del **Instituto** de la **Soldadura** (Madrid)
Boletin del **Instituto Geol**ógico y **Min**ero de **España** (Madrid)
Boletin Minero e **Industr**ial (Bilbao)
Brennstoff-**Wärme-Kraft** (Düsseldorf)
British Coal Utilisation Research Association, Monthly Bulletin (London)
British Coke Research Association, Technical Papers (London)
British Dental Journal (London)
British Electrical and **Allied Industries Research Association, Reports** (London)
British Engineering (London)
British Iron and **Steel Federation, Monthly Statistical Bull**etin (London)

British Iron and Steel Research Association, Reports (London)
British Journal of Applied Physics (London)
British Steelmaker (London)
Brown-Boveri Review (Baden)
Bulletin of the American Ceramic Society (Columbus, O.)
Bulletin, American Society for Testing Materials (Philadelphia)
Bulletin of the British Scientific Instrument Research Association (London)
Bulletin, British Steel Founders' Association (Sheffield)
Bulletin de Cercle d'Etudes des Métaux (St. Etienne)
Bulletin and Foundry Abstracts of the British Cast Iron Research Association (Birmingham)
Bulletin of the Geological Institute of the Upsala University (Upsala)
Bulletin de l'Institut Polytechnique de Jassy (Jassy, Roumania)
Bulletin of the Institution of Metallurgists (London)
Bulletin of the Institution of Mining and Metallurgy (London)
Bulletin of Ohio State University Engineering Experiment Station (Columbus, O.)
Bulletin of the School of Mines and Metallurgy, University of Missouri (Minneapolis)
Bulletin des Sociétés Chimiques Belges (Brussels)
Bulletin of the University of Wisconsin, Engineering Experiment Station Series

Canadian Journal of Chemistry (Ottawa)
Canadian Journal of Physics (Ottawa)
Canadian Journal of Technology (Ottawa)
Canadian Metals (Toronto)
Canadian Mining Journal (Quebec)
Canadian Mining and Metallurgical Bulletin (Montreal)
Calore (Milan)
Centre de Documentation Sidérurgique, Circulaires d'Informations Techniques (Paris)
Ceramics (Leighton Buzzard)
Chaleur et Industrie (Paris)
Chemical Age (London)
Chemical Engineering (New York)
Chemical and Engineering Mining Review (Melbourne)
Chemical and Engineering News (Washington)
Chemical Engineering Progess (New York)
Chemické Listy (Prague)
Chemisch Weekblad (Amsterdam)
Chemist-Analyst (Phillipsburg, N.J.)
Chemistry and Industry (London)
Chimica e Industria (Milan)
Chimie Analytique (Paris)
Chimie et Industrie (Paris)
Circular of the National Bureau of Standards (Washington)
Circular of Ohio State University Engineering Experiment Station (Columbus)
Claycraft (London)
Coke and Gas (London)
Collection des Travaux Chimiques de Tchecoslovaque (Prague)
Colliery Guardian (London)
Colonial Geology and Mineral Resources (London)
Commonwealth Engineer (Melbourne)
Comptes Rendus de l'Académie Bulgare des Sciences (Sofia)
Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences (Paris)
Congres du Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique (Paris)
Corrosion (Houston, Texas)
Costruzioni Metalliche (Milan)
Coventry Engineering Society Journal (Coventry)

Dansk Teknisk Tidsskrift (Copenhagen)
Demag News (Duisburg)
Discovery (Norwich)
Discussions of the Faraday Society (London)
Dyna (Barcelona)

E.S.C. News (Sheffield)
Echo des Mines (Paris)
Edgar Allen News (Sheffield)
Edison Electric Institute Bulletin (Philadelphia)
Eidgenossische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, Berichte (Zürich)
Electrical Engineer and Merchandiser (Melbourne)
Electrical Power Engineer (London)
Electrical Review (London)
Electrical Times (London)
Electrician (London)
Electronic Engineering (London)
Electroplating (London)
Elektrowärme Technik (Mindelheim)
Endeavour (London)
Engineer (London)
Engineering (London)
Engineering and Boiler House Review (London)
Engineering Inspection (London)
Engineering Journal (Montreal)
Engineering and Mining Journal (New York)
Engineering Research Bulletin, University of Michigan (Ann Arbor)
Engineers' Digest (London)
English Electric Journal (Stafford)
Escher-Wyss News (Zürich)
Études et Documentation Métallurgiques (Paris)
Experimentia (Basle)

Fonderie (Paris)
Forschung auf dem Gebiete des Ingenieurwesens (Düsseldorf)
Foundry (Cleveland)
Foundry Trade Journal (London)
Freyn Design (Chicago)
Fuel (London)
Fuel Economy Review (London)

G.E.C. Journal (London)
Galvano (Paris)
Gas Heat in Industry (Leighton Buzzard)
Gas Times (Watford)
Gas World (London)
Gazzetta Chimica Italiana (Rome)
Génie Civil (Paris)
Geologiska Föreningens, Förhandlingar (Stockholm)
Giesserei (Düsseldorf)
Gjuteriet (Stockholm)
Glückauf (Essen)
Hutnické Listy (Prague)
Hutnik (Prague)
Hutnik (Warsaw)
IVA Ingeniörs Vetenskaps Akademien (Stockholm)
Illinois University Engineering Experiment Station (Urbana)
Circular
Bulletin
Indian Engineering (Calcutta)
Indian Journal of Physics (Calcutta)
Industria y Química (Buenos Aires)
Industrial Chemist (London)
Industrial and Engineering Chemistry (Washington)
Industrial Finishing (Leighton Buzzard)
Industrial Gas (Leighton Buzzard)
Industrial Heating (Pittsburgh)
Industrial Heating Engineer (London)
Industrie Nationale (Paris)
Ingenieria e Industria (Buenos Aires)
Ingénieur Chimiste (Brussels)
Ingeniörs Vetenskaps Akademien, Handlingar (Stockholm)
Institut pour l'Encouragement de la Recherche Scientifique, Comptes Rendus de Recherches (Brussels)
Institute of British Foundrymen, Papers (Manchester)
Institute of Fuel, Paper (London)
Institute of Petroleum, I.P. Review (London)
Institution of Gas Engineers, Communications (London)
Instituto del Hierro y del Acero (Madrid)
Instituto de la Soldadura, Publicacíon (Madrid)
Instrument Practice (London)
Iron Age (New York)
Iron and Coal Trades Review (London)
Iron and Steel (London)
Iron and Steel Engineer (Pittsburgh)
Iron and Steel Institute, Special Reports (London)

Jernindustri (Oslo)
Jernkontorets Annaler (Stockholm)
Journal of the American Ceramic Society (Columbus, Ohio)
Journal of the American Chemical Society (Washington, D.C.)
Journal of the American Society of Naval Engineers (Washington, D.C.)
Journal of the American Water Works Association (New York)
Journal of the American Zinc Institute (New York)
Journal of Applied Chemistry (London)
Journal of Applied Mechanics (New York)
Journal of Applied Physics (New York)
Journal of the Birmingham Metallurgical Society (Birmingham)
Journal of the British Institution of Radio Engineers (London)
Journal of the British Shipbuilding Research Association (London)
Journal of the Chemical, Metallurgical and Mining Society of South Africa (Johannesburg)
Journal of Chemical Physics (New York)
Journal of the Chemical Society (London)
Journal de Chimie Physique (Paris)
Journal of the Council for Scientific and Industrial Research (Melbourne)
Journal of Dental Research (Baltimore)
Journal of the Electrodepositors' Technical Society (London)
Journal of the Electrochemical Society (Baltimore)
Journal du Four Electrique (Paris)
Journal of the Franklin Institute (Lancaster, Pa.)

Journal of the **Indian Chemical Society** (Calcutta)
Journal of the **Institute of Australian Foundrymen** (Melbourne)
Journal of the **Institute of Fuel** (London)
Journal of the **Institute of Metals** (London)
Journal of the **Institute of Petroleum** (London)
Journal of the **Institution of Automotive and Aeronautical Engineers** (Melbourne)
Journal of the **Institution of Civil Engineers** (London)
Journal of the **Institution of Engineers, Australia** (Sydney)
Journal of the **Institution of Heating and Ventilating Engineers** (London)
Journal of the **Institution of Locomotive Engineers** (London)
Journal, **Institution of Mechanical Engineers** (London)
Journal of the **Institution of Production Engineers** (London)
Journal of The **Iron and Steel Institute** (London)
Journal of **Mechanical Laboratory** (Tokyo)
Journal of **Metals** (New York)
Journal of the **Optical Society of America** (New York)
Journal of **Petroleum Technology** (Dallas, Texas)
Journal of the **Physical Society of Japan** (Tokyo)
Journal de **Physique et le Radium** (Paris)
Journal of the **Royal Institute of Chemistry** (London)
Journal and **Proceedings of the Royal Society of New South Wales** (Sydney)
Journal and **Record** of **Transactions of the Junior Institution of Engineers** (London)
Journal of **Research of the National Bureau of Standards** (Washington, D.C.)
Journal of the **Royal Aeronautical Society** (London)
Journal of the **Royal Artillery** (London)
Journal of the **Royal Institute of British Architects** (London)
Journal of the **Royal Microscopical Society** (London)
Journal of the **Royal Society of Arts** (London)
Journal of the **Royal Statistical Society** (London)
Journal of the **Royal Technical College** (Glasgow)
Journal of **Scientific Instruments** (London)
Journal of the **Scientific Research Institute** (Tokyo)
Journal of the **Society of Glass Technology** (Sheffield)
Journal of the **South African Institution of Mechanical Engineers** (Johannesburg)
Journal and **Transactions of the Society of Engineers** (London)
Journal of the **West of Scotland Iron and Steel Institute** (London)

Kohászati Lapok (Budapest)
Kungl. Tekniska Hogskolan, Handlingar (Stockholm)
Laboratoria N.V. Philips' Gloeilampfabrieken, Separaat (Eindhoven)
Lastechniek (The Hague)
Light Metal Age (Chicago)
Light Metals (London)

Machine Design (Cleveland, Ohio)
Machine Shop Magazine (London)
Machinery (Brighton)
Machinist (London)
Manchester Association of Engineers, Preprints (Manchester)
Maquinas e Metais (Lisbon)
Materials and Methods (New York)
Mechanical Engineering (New York)
Mechanical Handling (London)
Mechanical World (London)
Memoirs of the Geological Survey of India (Calcutta)
Memoirs of the Kyushu University (Hukuoka, Japan)
Mémoires de la Société des Ingénieurs Civils de France (Paris)
Mémorial de l'Artillerie Française (Paris)
Metal Finishing (New York)
Metal Industry (London)
Metal Powder News (New York)
Metal Progress (Cleveland, Ohio)
Metal Treating (New Rochelle, N.Y.)
Metal Treatment and Drop Forging (London)
Metalen (The Hague)
Metall (Berlin)
Metalloberfläche (Munich)
Metallurgia (Manchester)
Metalurgia y Electricidad (Madrid)
Metallurgia Italiana (Milan)
Métallurgie et la Construction Mécanique (Paris)
Métaux-Corrosion-Industries (Paris)
Metropolitan Vickers Gazette (Manchester)
Michigan University (Ann Arbor)
Engineering Research Bulletins
Engineering Research Circulars
Microtecnic (Lausanne)
Mine and Quarry Engineering (London)
Mineração e Metalurgia (Rio de Janeiro)
Mineralogical Magazine (London)
Mines Magazine (Denver, Colo.)
Mining, Electrical and Mechanical Engineer (Manchester)
Mining Engineering (New York)
Mining Journal (London)
Mining Magazine (London)
Mitteilungen aus dem Max-Planck-Institut für Eisenforschung (Düsseldorf)
Modern Metals (Chicago)
Müegyetemi Kozlemenyek (Budapest)
Murex Review (Rainham, Essex)

National Physical Laboratory, Reports (Teddington)
Nature (London)
New Zealand Engineering (Wellington)
New Zealand Journal of Science and Technology (Wellington)
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Nucleonics (New York)

Oil Engine and Gas Turbine (London)
Operational Research Quarterly (London)
Ossature Métallique (Brussels)
Österreichischer Maschinenmarkt und Elektrowirtschaft (Vienna)
Overseas Engineer (London)
Peintures, Pigments, Vernis (Paris)
Philippine Geologist (Manila)
Philippine Journal of Science (Manila)
Philips Research Reports (Eindhoven)
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Philosophical Transactions of the Royal Society (London)
Physica (The Hague)
Physical Review (New York)
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Powder Metallurgy Bulletin (Yonkers, N.Y.)
Power and Works Engineer (London)
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Prace Głównego Instytutu Metalurgii (Katowice)
Pratique du Soudage (Brussels)
Precision Metal Molding (Cleveland)
Proceedings, American Gas Association (New York)
Proceedings of the American Society for Testing Materials (Philadelphia)
Proceedings of the...Annual Convention of the American Electroplaters' Society (Jenkintown, Pa.)
Proceedings, Australasian Institute of Mining and Metallurgy (Melbourne)
Proceedings of the Cambridge Philosophical Society (London)
Proceedings, Chemical Engineering Group (London)
Proceedings, Diesel Engine Users' Association (London)
Proceedings of the Durham Philosophical Society (Durham)
Proceedings of the Ebbw Vale Metallurgical Society (Ebbw Vale)
Proceedings of the Indian Academy of Sciences (Bangalore)
Proceedings of the Indiana Academy of Sciences (Greencastle, Ind.)
Proceedings of the Institute of Australian Foundrymen (Melbourne)
Proceedings of the Institute of British Foundrymen (Manchester)
Proceedings of the Institution of Electrical Engineers (London)
Proceedings, Institution of Mechanical Engineers (London)
Proceedings of the Institution of Mechanical Engineers, Automobile Division (London)
Proceedings of the Lincolnshire Iron and Steel Institute (Scunthorpe)
Proceedings, Metal Powder Association (New York)
Proceedings, Natural Gas Department of the American Gas Association (New York)
Proceedings of the Nova Scotian Institute of Science (Halifax)
Proceedings of the Physical Society (London)
Proceedings of the Royal Canadian Institute (Toronto)
Proceedings of the Royal Institution of Great Britain (London)
Proceedings of the Royal Society (London)
Proceedings of the Royal Society of Edinburgh (Edinburgh)
Proceedings of the Society of Antiquaries of Newcastle upon Tyne
Proceedings, Society of Chemical Industry, Victoria (Melbourne)
Proceedings of the Society of Experimental Stress Analysis (Cambridge, Mass.)

LIST OF PERIODICALS

Proceedings of the South Wales Institute of Engineers (Cardiff)
Proceedings of the Staffordshire Iron and Steel Institute (Walsall)
Product Engineering (New York)
Product Finishing (London)
Products Finishing (Cincinnati)
Pro-Metal (Berne)
Przeglad Odlewnictwa (Prague)
Przeglad Techniczny (Warsaw and Lodz)
Publications de l'Association des Ingénieurs de la Faculté Polytechnique de Mons (Mons)
Publications de l'Institut de Recherches de la Sidérurgie (St. Germain-en-Laye)
Purdue University, Engineering Experimental Department (Lafayette, Ind.)
  Engineering Extension Series
  Engineering Research Series
Quarterly Journal of the Geological, Mining, and Metallurgical Society of India (Calcutta)
Quarterly Journal of the Geological Society (London)
Quarterly Journal of Mechanics and Applied Mathematics (Oxford)
Quarterly Transactions of the Society of Automotive Engineers (New York)
Queensland Government Mining Journal (Brisbane)
Railway Engineering Abstracts (London)
Railway Gazette (London)
Recherche Aéronautique (Paris)
Records of the Geological Survey of India (Calcutta)
Recueil des Travaux Chimiques des Pays-Bas (The Hague)
Refractories Journal (London)
Regional Technical Meetings of the American Iron and Steel Institute (New York)
Reports of the Scientific Research Institute (Tokyo)
Research (London)
Research Association of British Paint, Colour and Varnish Manufacturers' Review (Teddington)
Review of Scientific Instruments (New York)
Reviews of Modern Physics (New York)
Revista de Ciencia Aplicada (Madrid)
Revista di Meccanica (Milan)
Revista de Química Industrial (Rio de Janeiro)
Revue de l'Aluminium (Paris)
Revue de la Faculté des Sciences de l'Istanbul University (Istanbul)
Revue Générale de Mécanique (Paris)
Revue de l'Industrie Minérale (St. Etienne)
Revue de Métallurgie (Paris)
Revue des Produits Chimiques (Paris)
Revue de la Soudure (Lastijdschrift) (Brussels)
Revue Technique Luxembourgeoise (Luxembourg)
Revue Universelle des Mines (Liège)
Rheology Bulletin (New York)
Ricerca Scientifica (Rome)
Rivista di Meccanica (Milan)
Roll'schen Eisenwerke A. G. (Gerlafingen, Switzerland)
  Mitteilungen
  Werkzeitung
Royal Australian Chemical Institute (Melbourne)
  Journal and Proceedings
  Reviews of Pure and Applied Chemistry
Rozpravy (Prague)

S.A.E. Journal (New York)
Schweissen und Schneiden (Brunswick)
Schweisstechnik (Vienna)
Schweizer Archiv für Wissenschaft und Technik (Solothurn, Switzerland)
Science (Washington)
Science Abstracts (London)
Science and Engineering (Calcutta)
Science Reports of the Research Institutes, Tôhoku University (Sendai, Japan)
Scientific Proceedings of the Royal Dublin Society
Sheet Metal Industries (London)
Shipbuilder (Newcastle-on-Tyne)
Silicates Industriels (Brussels)
Société Royal Belge des Ingenieurs et des Industriels (Brussels)
  Bulletin Technique
  Mémoires
Spectrochimica Acta (Vatican City)
Spectrographic News Letter (Glendale, Calif.)
Stahl und Eisen (Düsseldorf)
Stanki i Instrument (Moscow)
Statens Provningsanstalt (Stockholm)
  Berättelse
  Meddelande
Steam Engineer (London)
Steel (Cleveland, Ohio)
Steel Processing (Pittsburgh)
Strojirenstvi (Prague)
Structural Engineer (London)
Sudostroyennie (Leningrad)
Sulzer Technical Review (Winterthur)
Sveriges Geologiska Undersökning, Årsbok (Stockholm)
Svetsaren (Gothenburg)
Swansea and District Metallurgical Society, Paper (Gorseinon)

Technik (Berlin)
Technique et Humanisme (Liège)
Technique et Science Aéronautiques (Paris)
Techniques et Civilisations (St. Germain-en-Laye)
Tecnicale Industria (Buenos Aires)
Tecnica Metalúrgica (Barcelona)
Teknisk Tidskrift (Stockholm)
Teknisk Ukeblad (Oslo)
Tidsskrift for Kjemi, Bergvesen og Metallurgi (Oslo)
Tin and its Uses (Greenford)
Tisco Review (Calcutta)
Transactions of the American Foundrymen's Society (Chicago)
Transactions of the American Institute of Electrical Engineers (New York)
Transactions of the American Institute of Mining and Metallurgical Engineers (New York)
Transactions of the American Society of Mechanical Engineers (New York)
Transactions of the American Society for Metals (Cleveland, Ohio)
Transactions of the British Ceramic Society (Stoke-on-Trent)
Transactions of the Canadian Institute of Mining and Metallurgy (Montreal)
Transactions of the Danish Academy of Technical Sciences (Copenhagen)
Transactions of the Faraday Society (London)
Transactions of the Indian Institute of Metals (New Delhi)
Transactions of the Institute of Marine Engineers (London)
Transactions of the Institute of Welding (London)
Transactions of the Institution of Chemical Engineers (London)
Transactions of the Institution of Engineers and Shipbuilders in Scotland (Glasgow)
Transactions, Institution of Gas Engineers (London)
Transactions of the Institution of Mining Engineers (London)
Transactions of the Institution of Mining and Metallurgy (London)
Transactions of the Institution of Naval Architects (London)
Transactions of the Liverpool Engineering Society (Liverpool)
Transactions, Manchester Association of Engineers (Manchester)
Transactions of the Mining, Geological and Metallurgical Institute of India (Calcutta)
Transactions of the Newcomen Society (London)
Transactions of the North East Coast Institution of Engineers and Shipbuilders (Newcastle-on-Tyne)
Transactions of the Royal Canadian Institute (Toronto)
Transactions of the Royal Society of Canada (Ottawa)
Transactions of the Society of Instrument Technology (London)
Transactions of the South African Institute of Electrical Engineers (Johannesburg)
United Effort (Pittsburgh)
United States Bureau of Mines (Washington, D.C.)
  Bulletin
  Information Circular
  Reports of Investigations
  Technical Paper
United States Geological Survey, Bulletin (Washington)
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Usine Nouvelle (Paris)
Vacuum (London)
Värmländska Bergsmanneföreningens Annaler (Filipstad, Sweden)
Welder (Waltham Cross)
Welding Journal (New York)
Welding and Metal Fabrication (London)
Welding Research (London)
Werkstoff und Korrosion (Mannheim)
Western Metals (Los Angeles)
Wire Industry (London)
Wire and Wire Products (Stamford, Conn.)

Yearbook of the American Iron and Steel Institute (New York)
Yearbook of the Coke Oven Managers' Association (London)
Yearly Proceedings of the Association of Iron and Steel Engineers (Pittsburgh)

Zeitschrift für Erzbergbau und Metallhüttenwesen (Stuttgart)
Zeitschrift für Metallkunde (Stuttgart)
Zeitschrift des Vereines deutscher Ingenieure (Düsseldorf)

ORES—MINING AND TREATMENT

Handling Iron Ore at Yampi Sound. H. B. Fletcher. (*Mech. Handling*, 1950, **37**, Nov., 442–443). Hard hematite is worked by open-cast methods at Cockatoo Island four miles off the north-west coast of Western Australia. The electrically operated shovels, 27-ton side-dumping trucks, crushers, cranes, ship-loading equipment, and power station are described.—R. A. R.

Labrador Ore : Air Lift Supplies Railway and Mining Equipment. (*Iron Steel*, 1951, **24**, Aug., 373–374, 388). The development of the Ungava iron ore fields in Labrador, and the proposals for working them are outlined. Proved deposits amount to 400 million tons, the output aimed at being 20 million tons/year.—G. F.

The W1400 Walking Dragline at Corby. (*J. Iron Steel Inst.*, 1952, 170, Jan., 51–55). [This issue].

An Ore Unloading Plant at Baltimore, Maryland. (*Engineer*, 1951, **192**, Sept. 7, 307–311). This article describes the large import pier recently built for the Baltimore and Ohio Railroad Company at Curtis Bay. The new port will supply the major steelmaking centres of Eastern United States with seaborne iron ore from the newly developed deposits in Labrador, Venezuela, Chile, Liberia, and other countries. The pier, which has a handling capacity of 10 million tons of ore per year, can accommodate vessels of up to 40,000 tons and can unload a 30,000-ton ore carrier in 24 hr.—M. D. J. D.

Screening and Charging Practice Increases Furnace Yield. A. H. Fosdick. (*Steel*, 1951, **128**, June 18, 86–96). The author discusses the relative merits of sintering, nodulizing, briquetting, and pelletizing and describes four Dwight-Lloyd sintering machines at the Bethlehem Pa. plant of the Bethlehem Steel Co. Each machine is 6 ft. wide and 83 ft. 3 in. long with 500 sq. ft. of grate area and 13 wired boxes. The monthly capacity for the four machines is about 180,000 net tons of sinter. Splitting ores into over 1-in. lumps, $\frac{3}{8}$-in. nuts, running the fines through the sinter plant, and charging each size in the blast-furnace separately has proved highly successful in increasing production.—M. D. J. B.

Briquetting of Ores Fines for Steel Plants. K. Radzwicki, W. Madej, and W. Stronczak. (*Prace Glownego Inst. Met.*, 1951, No. 3, 173–181). [In Polish]. Very good results were obtained in briquetting ore concentrates by Jarcho's method (used in U.S.S.R.) in which fines are mixed with small amounts of iron filings, water, and sodium chloride (0·5–1%). The method is based on corrosion processes which bind ore particles together. The highest strength of briquettes and the shortest time of hardening are obtained when the components are mixed so as to obtain the highest temperature increase during the corrosion process. Best results are obtained if the mix is pressed when at its highest temperature. However, sodium chloride is objectionable due to the destructive influence of alkali on refractory linings. Experiments were therefore made in which CaO, HCl, $MgCl_2$, H_2SO_4, ferrous sulphate, and spent pickling liquor were used as substitutes for sodium chloride. Investigations were made with ore concentrates containing Fe 71·2%, SiO_2 1·57%, CaO 2·29%, MgO 0·43%, P 0·13%, and S 0·039%. In laboratory experiments cylindrical briquettes (dia. and height about 50 mm., weight about 400 g.) were made at a pressure of 250 kg./sq. cm. Industrial briquettes (250 × 130 × 65 mm. weighing 6–7 kg.) were made on a brick-making machine at the same pressure. Fresh briquettes were left in the air under cover, and samples were tested every day for strength to follow the process of hardening. Minimum requirements for a briquette were taken from Russian practice, namely : (1) Compression strength min. 50 kg./sq. cm. ; (2) shatter test : a briquette dropped twice on a steel plate from a height of 2 m. must not produce more than 10% fines (below 5 mm.) ; (3) porosity not more than 5–10% ; (4) briquettes must not crumble when kept for 3 min. at 1500° C. Other requirements were : Fe 62% min. ; SiO_2 8% max. ; 5% max. of other slag-producing components ; water 2% max. (including combined water 0·5% max.) ; P 0·03% max. ; and S 0·03% max. In the first trials CaO was used as a binder without iron filings as the formation of $CaCO_3$ during hardening was expected to provide briquettes of sufficient strength. The results were unsatisfactory. In further experiments the Jarcho method was followed. The proportions of ore, iron filings, and water were 100/7/7 or 100/7/6. Briquettes made with HCl or $MgCl_2$ were unsatisfactory. Acetic acid (more than 0·15%) produced strong briquettes. For economic reasons this reagent could not be used on an industrial scale. Briquettes made with H_2SO_4 (0·2%) were strong (compression test above 110 kg./sq. cm., shatter test 5–6%), resisted atmospheric influence, stood up to loading and transport very well and, when added to the open-hearth bath, retained their shape and showed oxidizing properties as good as the best lump ores. Ferrous sulphate and spent pickling liquor also gave satisfactory results. When spent liquor is used, the moisture content of the concentrates must not be higher than 3–4%. When H_2SO_4 or spent pickling liquor is used, 0·02 to 0·03% of sulphur is introduced into briquettes. This does not cause serious difficulty in using these briquettes in steelmaking and it is considered less detrimental than the destructive influence of alkali on refractory linings.—V. G.

Research on Mineral Flotation. R. R. Bates. (*Industria y Química*, 1950, **12**, Sept.–Oct., 242–243). [In Spanish]. The author surveys the work of Taggart, Wark, and Con on ore flotation.—R. S.

Ironstones of the British Jurassic Rocks. A. Nelson. (*Iron Coal Trades Rev.*, 1951, **163**, Sept. 7, 547–550). The author outlines the geological history of the British Jurassic rocks and describes their locations. The past and present methods of mining and open-cast working are discussed.—G. F.

FUEL—PREPARATION, PROPERTIES, AND USES

Waste-Heat Yield in Iron and Steel Works According to Its Nature, Amount, and Value. K. E. Poppe. (*Stahl u. Eisen*, 1951, **71**, July 19, 769–773). Waste heat is best utilized by returning it in the same cycle to its source, as is done in feed-water and air preheaters for boiler plant, and recuperators or regenerators in furnaces ; steam raising and water heating are the next best methods. Waste-heat sources in power plants, blast-furnaces, basic converters, rolling mills, open-hearth furnaces, large gas engines, and pulverized coal-fired furnaces are evaluated according to temperatures and available quantities, and waste-heat balances for the last three years are presented.—A. G.

A Study of the Float and Sink Analysis of Coal, with Special Reference to the Effect of Variation in the Moisture Content of the Coal. W. H. D. Savage, P. A. M. Brink, J. M. v. d. Merwe, and P. Le R. Malherbe. (*J. Chem. Met. Min. Soc. S. Africa*, 1951, **52**, July, 1–11). Laboratory float and sink analyses on air-dried coal gave satisfactory separations at high gravities, but results at lower gravities were liable to considerable variations, which were dependent on the moisture content of the coal. The more moisture, the lower was the yield of float. Thus, coal should be conditioned before testing. Closely controlled air drying would require expensive air-conditioned chambers, and complete drying would give results of doubtful value. Thorough wetting by immersion is advantageous requiring only simple apparatus, which is described. The surface moisture on the sample presents no difficulties if zinc chloride solutions are used as separating media instead of organic liquids.—T. E. D.

Results of Russian Work in the Field of Utilization of Solid Fuels. A. B. Csernisev. (*Kohászati Lapok*, 1951, **6**, No. 3, 50–55). [In Hungarian]. Large coal processing plants were to have been built between 1946 and 1950 for treating coking coal with over 7% ash and other hard coal with more than 10% ash. Methods have been developed for : (1) Gasification of small coal ; (2) heating melting furnaces with peat and simultaneously producing gas with a high calorific value ; and (3) using peat to produce a coke for case-hardening steel—E. G.

The New Coke Ovens of S.A. John Cockerill and S.A. Métallurgique D'Espérance-Longdoz. P. Brichant. (*Rev. Univ. Mines*, 1951, **7**, May, 145–163). Automatic control has been used extensively at these new batteries of Coppée coke ovens. The oven dimensions are 13·5 m. long, 4 m. high, and 0·46 m. mean width. Plans and photographs are presented.—B. G. B.

Investigations Relating to the Production of Metallurgical Coke from South African Coals. T. D. Morgan, J. P. Bossert, J. F. Harris and C. C. La Grange. (*J. Chem. Met. Min. Soc. S. Africa*, 1951, **51**, Jan., 219–241). The production of metallurgical coke from South African coals was investigated by the Fuel Research Institute of South Africa. An 11·58 cu. ft. experimental coke oven was heated electrically by silicon carbide resistance rods. The methods of analysing and testing the raw materials and the cokes produced are indicated. Many coals and blends were tested and preliminary

results are given. No very encouraging results were obtained.—T. E. D.

The Production, Recovery, and Treatment of By-Products at German Coking Plants. H. P. Shaw. (*Yearbook Coke Oven Man. Assoc.*, 1951, 237–253). Coking plants in the Ruhr area and the carbonization of Ruhr coal are discussed. The by-products considered are tar, ammonia, benzole, sulphur, gas, and phenol. Measures taken to avoid the cracking of hydrocarbons are indicated. Units of the by-product recovery plant are described with details of the working up of the by-products.—T. E. D.

The Oil Washing of Coke Oven Gas Under Pressure. H. S. Illingworth. (*Yearbook Coke Oven Man. Assoc.*, 1951, 185–199). At the Hemsworth and United Kingdom Coke Oven Co. Ltd. at Fitzwilliam, Yorks., the oil-washing process is used for removing organic sulphur and benzole from town gas supplied from the coke ovens. The purified gas has to be supplied at pressure, and advantage is taken of this to wash the gas after compression; the maximum pressure in the washing system is 30 lb. The plant is briefly described and a gas-flow diagram is given.—T. E. D.

Thermal Efficiency of Coke Oven Batteries. A. Taylor. (*Yearbook Coke Oven Man. Assoc.*, 1951, 200–221). The thermal performance of coke ovens is reviewed and discussed. It includes the effect of coking rate, ways in which heat supplied to the ovens is used and lost, effect of flue temperature and practical factors affecting oven performance. The most uncertain factor affecting underfiring is the amount of heat required by the charge. Surface heat loss is about 10% of the heat input. Stack losses increase rapidly with excess of air, 80% excess air resulting in the use of 10% more fuel. (22 references).—T. E. D.

The Production and Utilisation of Coke Oven Gas. H. D. Greenwood. (*Yearbook Coke Oven Man. Assoc.*, 1951, 122–150). Details of the quantity of coke-oven gas produced and the amount used by various consumers are given and the economics of production and distribution are considered.

Analysing Blast-Furnace Gas. (*Iron Steel Eng.*, 1951, **28**, Aug., 143). **Analyzer Controls Gas Cleaning Equipment at Blast Furnaces.** (*Steel*, 1951, **129**, Aug. 27, 90, 94, 96). A description is given of a blast-furnace gas analyser and alarm developed by the General Power Plant Corp. to provide a continuous record of the dust content. The recorder is an electronic circuit which measures the difference in output between two photronic cells and sounds an alarm when the dust concentration exceeds a predetermined limit.—M. D. J. B.

The Sampling of Dust-Laden Gases. C. J. Stairmand. (*Trans. Inst. Chem. Eng.*, 1951, **29**, 15–44). The general principles of sampling dust-laden gases are described. Recommended forms of mixing baffles are given, together with values for the pressure losses imposed. Isokinetic sampling is desirable; errors likely to result from non-isokinetic sampling are indicated. Details of satisfactory sharp-edged sampling nozzles are given, and a design for an air- or steam-operated ejector for extracting the sample is suggested. Detailed descriptions and operating data for several types of filter are given and a self-compensating electrostatic sampler which allows sampling over the range 20–100 ft./sec. is described.—T. E. D.

Dust Collection by Impingement and Diffusion. C. J. Stairmand. (*Trans. Inst. Chem. Eng.*, 1950, **28**, 130–139). The mechanism of impingement filtration is discussed, with particular reference to fibre filters. The extremely high efficiency of slag wool filters is explained. The impingement principle is extended to spray dedusters, which include the venturi scrubber and the rotary distintegrator.—T. E. D.

TEMPERATURE MEASUREMENT AND CONTROL

A Period Immersion Pyrometer. R. F. Wright and E. Scorah. (*J. Iron Steel Inst.*, 1951, **169**, Nov., 243–244). A method of period immersion pyrometry has been developed for use on high-frequency furnaces using normal types of immersion pyrometer fitted with fused alumina dipping tubes which are coated with alumina cement to minimize heat shock. Immersion periods of up to two hours have been obtained. Experiments in other uses of the technique are mentioned. An appendix by T. Land and R. Barber describes an alternative method of thermal shock protection by enclosing the alumina tube in a steel sheath.

Control of Liquid-Steel Temperatures in Hearth and Ladle. F. A. von Gruenigen and W. D. Lawther. (*Amer. Inst. Min. Met. Eng., Proc.*, 1950 *Open Hearth Conf.*, **33**, 114–127). Using immersion pyrometers the bath temperature at tap may be controlled within approx. ± 10° F. This does not result in control of pouring temperature since: (1) With a normal ladle the last metal poured is hotter than that poured earlier; (2) The quantity of ferro-alloy additions to the ladle and the type of deoxidizer used affect the temperature loss at tap and the resultant pouring temperature—an aluminium-deoxidized heat pouring 30–40° F. higher than a similar untreated heat; and (3) the temperature to which a ladle is preheated has little effect upon the temperature loss between tapping and pouring.—F. C.

The Development of the Instrumentation of the Open Hearth Furnace in France. G. Husson and P. Rodicq. (*Trans. Soc. Instrument Techn.*, 1950, **2**, Sept.–Dec., 41–44). Instrumentation and control of open-hearth furnaces burning mixed coke-oven and blast-furnace gas are described using the 200–210 ton/day Maerz furnace at Aciéries de Longwy as an example. The roof temperature is measured by a radiation pyrometer; all other temperatures are measured by chromel alumel thermocouples with recorders. A list of instruments is given for controlling the Hilger gas producers and open-hearth furnaces at Le Creusot.—H. D. W.

Applications of the Electronic Tubes to the Measurements of Temperature. J. Schwartz. (*Microtecnic*, 1951, **5**, Jan.–Feb. 18–23; Mar.–Apr., 66–70). Schematic diagrams show the use of pre-amplification when a thermistor is employed as a thermosensitive element. By adding stages the output may be fed direct to a cathode-ray tube. The design of automatic compensating amplifiers is discussed. For this purpose the application of A.C. voltage amplifiers is most satisfactory. The reliability of radio tubes for long periods of operation is examined.—H. D. W.

The Measurement of Surface Temperature. R. C. Parker. (*Trans. Soc. Instrument Techn.*, 1951, **3**, June, 54–64). Methods of surface-temperature measurements are discussed. Where the surface may be contacted and is below 700° C., thermocouples may be used if the surface is stationary and temperature gradients are absent. At above 700° C., contact is not normally possible and measurement is based on the emission of radiant energy. The theory of total-radiation pyrometry and the application of the thermopile and the bolometer are described—M. D. W.

Temperature Measurement in Gases and Flames—Radiation Methods. R. Jackson. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1951, **15**, June, Review Series No. 104, 205–219). The literature is reviewed. (63 references).

Newer Methods of Gas Temperature Measurement. R. Jackson. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1951, **15**, July, Review Series No. 105). The literature is reviewed with special reference to methods of temperature measurement when the gases are at varying temperatures, or moving at high velocity and at a pressure differing from atmospheric. (70 references).—R. A. R.

REFRACTORY MATERIALS

Manufacture of Refractory Magnesite at the Plants of Veitscher Magnesitwerke A.G. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 24, 431–433). Brief descriptions are given of the plant and equipment of the three main works of the Veitscher Magnesitwerke A.G., at Veitsch, Trieben, and Breitenau, which exploit the high-grade Styrian magnesite deposits. The products include 'Steelklad' metal-cased bricks.—G. F.

Manufacture of Refractories by Oesterreichisch Amerikanische Magnesit A.G. at Radenthein. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 24, 405–407, 414). This article deals with the manufacture of magnesite refractory bricks at the Austro-American Magnesite Company's works at Radenthein.—G. F.

Utilization of Piedmontese Silico-Magnesian Materials in the Manufacture of Forsterite Refractories. V. Cirilli and C. Brisi. (*Met. Ital.*, 1951, **43**, Sept., 379–382). The possibilities of using the silico-magnesian materials, found in large quantities in Piedmont, are considered for the manufacture of forsterite refractories. Tests on specimen bricks show these to have high refractory characteristics.—M. D. J. B.

The Production of Sintered Alumina Ware. T. G. Carruthers. (*Metallurgia*, 1951, **44**, Aug., 103–107). The production of sintered alumina crucibles and tubes, using a slip-casting technique, is described. Pressing and other methods of forming special shapes are briefly mentioned. The technique of firing the ware is outlined.—J. B. B.

The Influence of Preliminary Gas Treatment on Reactivity of Solids, Especially in the Silica and Alumina Systems. J. A. Hedvall. (*Silicates Indust.*, 1951, **16**, June–July, 157–167). [In English]. In the recrystallization and cracking of glazes and in reactions of the type $SiO_2 + CaO$ and $Al_2O_3 + CaO$ a significant influence of gases is observed. The effect of oxygen, SO_2, SO_3 + air, and SO_3 upon the reactivity of all the allotropic forms of silica and alumina in combining with calcium oxide was studied in the 700–1000° C. range. In the experiments involving Al_2O_3 and those involving SiO_2, pretreatment of the powdered SiO_2 and Al_2O_3 with oxygen and SO_2 facilitated the completion of the reactions and increased their velocity ; the opposite was found to be the case with SO_3 and with the SO_2–air mixture.—P. F.

Effect of Forming by Discharge Presses on the Internal Structure of Pressed Bricks. V. Licini. (*Met. Ital.*, 1951, **43**, Aug., 333–336). An investigation of the phenomena occurring in the internal structure of silico-aluminous firebricks formed by pressing a moist paste is reported.—M. D. J. B.

Design of Dilatometer for the Determination of the Absolute Density of Refractory Products. J. Baron. (*Chim. Anal.*, 1951, **33**, Oct., 295–296). A dilatometer with a 100-c.c. bulb surmounted by a 5-c.c. reservoir and a tube graduated from 5 to 15 c.c. over a length of 200 mm. are described. The density range 1·33 to 4 can be covered for a 20-g. sample.—T. E. D.

Spectral Excitation of Powdered Refractory Materials. D. Johnston. (*Metal Treatment and Drop Forg.*, 1951, **18**, June, 270, 271). Work at Leeds University has shown that powdered samples of refractory materials, allowed to fall through a central hole in graphite electrodes which are excited by a conventional condensed spark circuit, will yield satisfactory line spectra. The design of the electrodes and of a simple rate-of-fall controlling device is shown.—P. M. C.

Fused Stabilized Zirconia Refractories in Commercial Production at Norton Plants. Parts I and II. S. S. Kistler. (*Indust. Heating*, 1951, **18**, Feb., 320–327). The history of the development of this refractory is described.

Fused Stabilized Zirconia Refractories. Part III—Properties and Uses of Stabilized Zirconia Products. O. J. Whittemore. (*Indust. Heating*, 1951, **18**, Mar., 512–516).

Fused Stabilized Zirconia Refractories. Part IV—Stabilized Zirconia as a Pure Oxide Refractory. L. H. Milligan. (*Indust. Heating*, 1951, **18**, Apr., 699–700).

Fused Stabilized Zirconia Refractories. Part V—Electric Furnace Fusion and Purification of Zirconia. D. W. Marshall. (*Indust. Heating*, 1951, **18**, May, 1082–1086).

Some Applications of Ethyl Silicate in Refractories. H. F. Scott and H. G. Emblem. (*Refract. J.*, 1951, **27**, July, 286–289). As commercial ethyl silicate will form a silica gel it is very useful for making refractories from non-plastic refractory substances. It is free from alkali metals, permits safe handling of green bodies, promotes dimensional stability, and may influence the course of mineralization. The preparation of ethyl silicate involves the reaction $SiCl_4 + 4C_2H_5OH \rightarrow Si(OC_2H_5)_4 + 4HCl$, but as the ethyl alcohol is not absolutely anhydrous part of the tetraethoxy silane is hydrolysed during manufacture, giving rise to higher polymers, which accounts for a silica content of about 40% compared with 28% for tetraethoxy silane. Acid and alkaline methods of hydrolysis, storage, gelation, and setting time are discussed.—E. J. D. S.

Trials of Refractories in Steel Plants. J. E. Pluck. (*Refract. J.*, 1951, **27**, July, 277–278). The purpose, procedure, and results of ladle and open-hearth refractory trials, carried out at one plant, are reviewed.—E. J. D. S.

Sillimanite Brick in Linings of Hot-Metal Mixers. F. A. Colledge. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 224–231). The use of a combination of blast-furnace-quality fireclay brick and sillimanite brick as opposed to a complete lining of blast-furnace fireclay brick in the 1300-ton cylindrical mixer at the Carnegie Illinois plant extended the normal compaign from 6 to 10½ months. During this period, with one repair after 6½ months, 401,600 tons passed through the mixer in 6½ months' operation, the previous best being 188,500 tons. The sillimanite brick was restricted to the sections of severest erosion, *i.e.*, on the front and back walls, the pour-in end wall and the spout. The higher cost of the sillimanite is justified.—F. C.

A Method of Estimating Thickness of Hot-Metal Mixer Linings. L. L. Wells, jun. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 238–241). The thickness of sections of hot-metal mixer linings below the nominal metal line may be estimated by measurement of the mixer-shell temperature.—F. C.

Performance of High Magnesia Ramming Mixes. R. Smith. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 242–244). Trials of a new high-magnesia ramming mix on 110-ton open-hearth furnaces showed that the new material compares satisfactorily with those previously used (*a*) for putting in new furnace bottoms, (*b*) for hot repair jobs and (*c*) for bank repairs at the slag line and renewal of tap-hole section.—F. C.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Design and Layout of Blast-Furnace Plant : Correct Spacing of Equipment as a Factor in Operating Efficiency. R. W. Johnson and R. Kingston. (*Iron Coal Trades Rev.*, 1951, **163**, Sept. 7, 527–536). The authors enumerate items of equipment necessary in a modern blast-furnace plant, and then discuss the design and the operation of each. Space requirements of both single and multiple furnace plants are considered.

Pig-Iron Production in Electric Furnaces : Use of Lignite as Substitute for Coke. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 17, 355–356). Experiments are being carried out in Austria to produce pig iron in electric furnaces, utilizing lignite. Results are given, indicating that Styrian sinter and Köflach lignite are very suitable for electric furnace smelting, both the desired analysis and high manganese recovery being obtained. Results are then given of experiments in reducing Styrian ore with Styrian lignite alone in a low-shaft oxygen-blown furnace, this process also proving economically possible.

Sulphur-Containing Alloys in Mining Technology, Metallurgy, and Cosmic Physics. R. Vogel. (*Z. Metallkunde*, 1951, **42**, July, 202–206). The significance of the study of the constitution and equilibria of metal–stone compounds in connection with the production of steels containing sulphides, for the explanation of the constitution of cosmic bodies and the structure of meteorities, is shown by means of several examples.—P. F.

Scientific Principles of Blast-Furnace Stove Design and Practical Implications. A Schack. (*Stahl u. Eisen*, 1951, **71**, July 19, 773–776). Temperature distribution and heat-transfer problems in checkers and factors affecting their design are analysed. Regenerators built in the shape of inverse truncated cones, with the number of conduits and refractory thickness increasing from the cold lower end towards the hot top end, are most efficient, successfully resist overheating, and are characterized by a very small temperature drop during blowing.—A. G.

International Research Project Studies—Low Shaft Blast Furnace. (*J. Met.*, 1951, **3**, Sept., 750). Several European countries are undertaking co-operative research on the low-shaft blast-furnace. One furnace of rectangular cross-section is being constructed at Liége and a second of circular cross-section at Oberhausen. The objects of the work and the programme are outlined.—G. F.

Influence of the Composition of Ores on Their Use in the Blast-Furnace. J. Laborne. (*Mét. Constr. Mécan.*, 1951, **83**, Aug., 573–577). When several siliceous and calcareous ores are used in the blast-furnace it is advisable to select one siliceous and one calcareous ore for a base in order to obtain uniform slag basicity. Uniformity of the free lime in the siliceous ore is much less important than that in the calcareous ore, and uniformity of silica in the ore is more important than that of lime.—R. A. R.

Radioactive Tracers in Blast-Furnace Exploration. (*Research*, 1951, **4**, Sept., 418–420). Two techniques, developed by the British Iron and Steel Research Association, for exploring blast-furnaces in operation, by means of radioactive tracers are described. The first is for the measurement of gas transit times through the furnace. The second is for measuring refractory wear in the furnace, by embedding pellets of cobalt^{60} into the lining bricks. When the brick has been worn away, the disappearance of the radioactivity, measured through the shell, or else the appearance of very slight radioactivity in the iron, is noted. Details of pellets are given, but results are not yet available.—C. J. B. F.

Blast Furnace Operation at High Top Pressure. R. P. Towndrow. (*West Scotland Iron Steel Inst.* Preprint, Apr. 13, 1951). When designing a furnace at Clyde Iron Works for high top-pressure operation provision was made for varying the conditions. An analysis was first made of working

under normal conditions. The necessary modifications to the furnace and its auxiliaries were then designed, and are described. Results with the new furnace are presented and compared with those obtained previously—P. C. P.

Desulphurisation of Pig Iron with Pulverised Lime. B. Kalling, C. Danielsson, and O. Dragge. (*Jernkontorets Ann.*, 1951, **135**, No. 3, 89–106 : *Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 732–735 ; *J. Met.*, 1951, Sept.). Desulphurizing pig iron as developed at Domnarfvet, Sweden is described. Molten iron is brought into intimate contact with powdered burnt lime containing coke powder, by treatment in a rapidly rotating furnace under strongly reducing conditions, the temperature being kept below 1400° C. After a consideration of the theory, the results of pilot-plant trials are given. Rapid and efficient desulphurization takes place, no external heat being required, and as no molten slag is formed, refractory attack is avoided. No dangerous smoke is formed during the process.—G. F.

Kalling-Domnarfvet Process at Surahammar Works. S. Fornander. (*Jernkontorets Ann.*,1951, **135**, No. 3, 107–115 ; *Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 739–741 ; *J. Met.*, 1951, Sept.) The practical application of the pig-iron desulphurization process described by Kalling, Danielsson, and Dragge (*see* preceding abstract) at Surahammar, Sweden, is described. The process is simple and inexpensive and removes about 90% of the sulphur in the molten iron. The construction and operation of the rotating furnace are described.—G. F.

Desulphurization of Pig Iron by Solid Lime. V. Giedroyc and T. E. Dancy. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 353–359). The possibility of using solid lime for desulphurizing pig iron was examined and the necessary data to assess the practicability of this process were obtained. These include measurements of the rate of reaction and the influence of sulphur concentration and temperature on the process. An estimate was made of the surface area of lime required to obtain a given degree of desulphurization.

A Corrected CO/CO_2 Ratio for Blast Furnaces. S. T. Killian. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 742–745 ; *J. Met.*, 1951, Sept.). A corrected CO/CO_2 ratio of blast-furnace gas is proposed as an index of blast-furnace performance. The corrected ratio, based on hydrogen-free gas with the CO_2 from the fluxes deducted from the gas analysis, will probably show changes in furnace performance more quickly than any other available method and, on iron of similar analysis, give a closer expression of the efficacy of the gasified carbon of the fuel in removing oxygen from the ore. The ratio varies inversely with production. Directions for calculating the corrected ratio are given.—G. F.

TREATMENT AND USE OF SLAGS

The Mineralogy of Blast-Furnace Slag. R. W. Nurse and H. G. Midgley. (*Silicates Indust.*, 1951, **16**, Aug.–Sept., 211–217). [In English]. Air-cooled slags from 21 ironworks were examined petrologically and analysed. Normal petrological examination by thin sections, sufficed in most cases, and details of etching methods are given. Tables of the optical properties and compositions of the phases likely to occur in slags are given, and the phase assemblages found are compared with those calculated from a knowledge of the system $CaO–MgO–SiO_2–Al_2O_3$. Under the conditions of cooling normally employed chemical equilibrium is not always maintained. Minerals likely to cause disintegration under certain circumstances are calcium orthosilicate and calcium sulphide. Free magnesia is not a probable constituent of slags even when a dolomite burden is employed.—P. F.

Some Metallurgical Aspects of the Constitution of Slags. E. Eyt. (*Silicates Indust.*, 1951, **16**, May, 144–146). Chromium ores of identical chemical composition but of different origin may vary in refractoriness owing to differences in constitution. The most refractory ones contain compounds of the spinel type, less refractory ores contain olivines and serpentines. The polarizing microscope reveals this difference. A much easier, but coarser method of identification is by stoichiometric analysis. Magnesia is a weak base at high temperature and behaves as such in magnesium silicate, which is then as easily destroyed as free silica. This is not so in the case of calcium silicate which decomposes only in so far as it contains silica in the free state as an admixture.—P. F.

PRODUCTION OF STEEL

Modern Steel Making—Reorganized Melting Shop in Large Steel Works. (*Elect. Rev.*, 1951, **149**, Sept. 21, 563–567). The reorganized melting shop of the Consett Iron Co., Ltd., comprising seven 150-ton and one 80-ton open-hearth furnaces and a 1000-ton hot metal mixer with its charging machines and other equipment is described with special reference to the electrical machinery.—E. A. E.

Steelmaking at Shotton : One Hundreth Anniversary of John Summers and Sons, Limited. (*Brit. Steelmaker*, 1951, **17**, Sept., 454–459). The year 1951 is the 100th anniversary of the firm of John Summers & Sons, Ltd., which specializes in the manufacture of steel sheet. After a review of the development of the firm, a description is given of the present-day works at Shotton.—G. F.

Stelco Expands. (*Canad. Metals*, 1951, **14**, Apr., 12–14). An account is given of the expansion programme of the Steel Company of Canada, which aims at a 50% increase of production capacity. Plant under construction, or projected, includes an ore and coal dock and storage facilities, 83 coke ovens, one blast-furnace of 28-ft. hearth dia., and four 250-ton furnaces.—E. C.

" Iscor " Works at Vanderbijl Park. (*Engineer*, 1951, **192**, Aug. 31, 281–284). This article describes the new works at Vanderbijl Park of the South African Iron and Steel Industrial Corporation Ltd. The initial output of the plant is rated at 350,000 ingot tons/year but provision is made for an ultimate output of 1,000,000 ingot tons. Details of the plant and main services are given.—M. D. J. D.

Austria's Steel Investment Programme. (*Brit. Iron Steel Fed., Monthly Stat. Bull.*, 1951, **26**, Aug., 6–10). A short survey is given of the development plans of the principal Austrian iron and steel works.—R. A. R.

Coke Ovens, Blast Furnaces and Steel Plant at Vereinigte Oesterreichische Eisen und Stahlwerke. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 24, 437–439). The Vereinigte Oesterreichische Eisen und Stahlwerke consists chiefly of coke ovens, blast-furnace plant, steelworks, rolling mills producing both plates and sheets, a foundry, forging shops, engineering and steel constructional departments, a power station, and complete facilities for research and development. These are described.—G. F.

Steelmaking and Rolling at Gebr. Böhler A.G. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 24, 417–420). The development of the steel industry in the Kapfenberg area of Austria is first discussed, followed by a description of the present-day facilities at the works of Gebr. Böhler A.G. Each steelmaking shop has both electric and open-hearth furnaces, and the total annual output is about 120,000 tons.—G. F.

Steel Melting and Wire Production at Felten & Guilleaume A.G. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 24, 415–416). A brief description is given of the Styrian works of Felton & Guilleaume A.G. at Bruck and Diemlach. At Diemlach the steelmaking plant has an annual capacity of 50,000 tons of ingots, which are rolled to rounds. The bulk of the wire rolled at Diemlach is drawn down at the Bruck works, which has an annual output of about 30,000 tons.—G. F.

Oesterreichisch-Alpine Montangesellschaft Organisation. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 24, 395–404). The general structure of the Oesterreichisch-Alpine Montangesellschaft organization and the development of the iron-ore mountain at Eisenerz and the mining methods are described. Details are given of the iron and steel works at Donawitz, wire-drawing installations at Ferlach, and rolling-mill plants at Kindberg.—G. F.

Plant Engineering in the Iron and Steel Industry. F. Mortimer. (*Iron Coal Trades Rev.*, 1951, **163**, Aug. 17, 337–345 ; Aug. 31, 497–503). A review is given of the work of the Plant Engineering Division of the British Iron and Steel Research Association since its formation in 1945. Four main research committees supervise the Division's work in four fields, namely, mechanical, civil, and electrical engineering, and fuel technology. The particular investigations described include the study of works layout, works traffic analysis and control, melting-shop design, open-hearth furnace charging, rolling-mill research, fuel efficiency in iron and steel production, and the design of steelworks cranes. The technical and commercial aspects of handling imported ore, are receiving special attention.—G. F.

Effect of Automatic Controls on Open Hearth Production at Lackawanna. R. M. Jordan. (*Iron Steel Eng.*, 1951, **28**, Aug., 63–66). A description is given of the open-hearth department of the Lackawanna plant of Bethlehem Steel Co. which consists of 30 furnaces in three open-hearth shops. The effects of temperature and combustion controls are discussed. Provided the furnace is sound, combustion controls and automatic reversal will help a furnace to produce more steel and use less fuel.—M. D. J. B.

Flow Patterns in Furnaces. J. H. Chesters. (*Chem. Indust.*, 1951, June 16, 448–455). Research by the United Steel Companies on flow patterns in open-hearth furnaces is reported. Principles were studied in two-dimensional Perspex models using powdered bakelite in water. Certain unstable systems, the intermingling of two jets, and the patterns formed by two jets close together and at right angles, were noted. These results also apply to three-dimensional systems formed by rotation or linear extension of two-dimensional ones. Perspex models of the Maerz and Venturi types of furnace were also used and the photographic technique is described. The results show that a large recirculation along the roof or sides occurs, and the question whether this is good or bad is discussed.—N. McE.

An Experimental Furnace for the Investigation of Open-Hearth Furnace Combustion Problems. Part V—Experiments with the Venturi Port and Modifications. J. F. Allen. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 37–44). [This issue].

An Experimental Furnace for the Investigation of Open-Hearth Furnace Combustion Problems. Part VI—Conclusions, Summary of Results and their Application. J. R. Hall and A. H. Leckie. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 44–48). [This issue].

New Developments in Scrap Handling for the Open Hearth. L. R. Rissler. (*Iron Steel Eng.*, 1951, **28**, Aug., 108–113). *See* 'Open Hearth Charging Time Cut 55%,' *J. Iron Steel Inst.*, 1951, **169**, Oct., 186.

How Good Materials Handling Helps Armco. G. F. Sullivan. (*Iron Age*, 1951, **167**, Mar. 22, 75–78). The hydraulic scrap hoist method of charging at the new open-hearth shop of Armco Steel Co., Middletown, allows easy repair to furnaces because there are no boxes or bogies cluttering up the floor. Burnt lime and other refractories are conveyed on belts to storage bins on the shop floor.—A. M. F.

Proposed Charging System Could Boost Open-Hearth Production. (*Steel*, 1951, **128**, Apr. 9, 90–92). A scheme is put forward for the rapid handling of scrap and other materials into the open-hearth furnace. It is claimed that, with a novel type of charging machine equipped with a 180-cu. ft. charging box, 100 tons of scrap can be put into the furnace in 15 min. A separate ore-stone-dolomite charger is designed to weigh and feed out up to 500 tons/hr. Because of the size of the scrap charging box—14½ ft. wide—the open-hearth furnace would have to have a suspended roof with no centre buckstays but with multiple, interlocking overhead doors.

Application of the Slag-Reaction Method in the Open-Hearth Melting Shop. E. Spetzler. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 197–204). Data and graphs are given in support of descriptions of several methods of producing steel, equivalent to the 'electric' type, in the open-hearth furnace. Slag deoxidation is the principle common to all methods, which differ mainly in details of application and the composition of the deoxidants used. Satisfactory alloy steels, closely equivalent to the 'electric' variety could thus be produced in quantity.—P. F.

Fuel Consumption in the Open-Hearth Furnace. A. J. Fisher. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 268–274). The author discusses fuel consumption in the oil-fired open-hearth furnace in terms of the two arbitrary functions, 'furnace efficiency' and 'flame efficiency,' the former being the average combustion-air preheat temperature between charge and tap divided by 2100° F., the latter being the ratio of average fuel consumption to maximum input. The design of the bath and checker system is considered.—F. C.

Optimum Firing Rates. G. C. Primm. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 277–282). The optimum firing rate of open-hearth furnaces is discussed from the standpoint of limitations imposed by: (1) The capacities of auxiliary equipment; (2) the design, construction, and materials of the furnace; and (3) shop equipment, raw materials, and personnel.—F. C.

Substitutes for Pig Iron—Economics and Effect on Production. R. C. Solomon. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 96–98). A short discussion of the factors determining the percentage of pig iron in the charge of a 200-ton open-hearth furnace is presented.—F. C.

Jet Tapping. H. W. Perry. (*Brit. Steelmaker*, 1951, **17**, Aug., 422–425). The author describes a new and improved method of tapping open-hearth furnaces, which is now in regular use by the Republic Steel Corporation. An explosive charge is used in the 'Jet Tapper,' the construction and operation of which are described. A quick, clean tap is obtained, and skull formation is considerably reduced.—G. F.

Factors Affecting Open-Hearth Productivity. W. G. Cameron and A. I. Aitken. (*West Scotland Iron Steel Inst.* Preprint, Mar. 31, 1951). The properties of available fuels for steelmaking are listed, and firing with rich and lean fuels is considered. The properties and uses of refractories are reviewed. The dimensions of 690 open-hearth furnaces are listed and their production characteristics analysed. Checker work is discussed and checker design calculations are explained. Reversing valves, flues, the all-basic furnace, and waste-heat recovery are dealt with.—P. C. P.

Oxygen Lancing in Electric Arc Steelmaking Furnaces; Recent Developments in British Practice. (*Iron Coal Trades Rev.*, 1951, **163**, Oct. 5, 739–743: *Engineer*, 1951, **192**, Oct. 5, 426–428). A session of the B.I.S.R.A. Steelmaking Conference on oxygen lancing is summarized. Lancing practice at works manufacturing stainless steels and plain-carbon steels are described and future possibilities of the technique considered.—G. F.

Use of Oxygen for the Decarburization of Electric Furnace Steels. M. Michaud. (*Met. Ital.*, 1951, **43**, Aug., 315–322). A classification of steels based on their behaviour towards oxygen decarburization is given. The advantages of using oxygen in the making of electric furnace steels and methods of injecting it are discussed.—M. D. J. B.

A Study of Some of the Physical Characteristics of Acid Open-Hearth Slags. C. R. Funk and K. Midlam. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 292–307). The appearance, fracture, and petrographic characteristics of slag pancakes and the fluidity of acid open-hearth slags taken at various stages during the heat have been correlated with SiO_2 and FeO content, Slag pancakes were grouped into six characteristic types (A–F) of decreasing oxidizing activity and correlation of these against chemical analyses showed (*a*) the SiO_2 content was not characteristic of the type of slag; (*b*) the slag type was a function of FeO content and fluidity; (*c*) as the slag develops from type A to F the oxidizing power decreases; this is thought to be due to the formation of crystals of an FeO.SiO_2 compound forming an inactive constituent of the slag which may or may not be soluble in the slag at steelmaking temperature. Fe_2O_3 is seldom present in the slag pancakes.—F. C.

The Influence of the Chemical Composition and Structure of Cast Iron on Ingot Mould Life. E. Bucko. (*Prace Badawcze Glownego Inst. Met.*, 1951, No. 3, 183–200). [In Polish]. The life of 79 square 5-ton ingot moulds was studied. The carbon plus silicon content of the moulds varied between 4·37 and 6·35%. The most durable moulds were from the hypoeutectic iron (C 3·50–3·70%, Si 1·0–1·75%). In the carbon plus silicon range of 5·20–5·60% the moulds with ferritic structure were the most durable, and in the 4·50–5·20% range the moulds with pearlitic-ferritic structure. The moulds with pearlitic structure (C + Si about 4·6%) had a much shorter life than those with pearlitic-ferritic structure. More than 0·45% manganese is undesirable because the manganese inhibits ferrite formation. More than 0·12% phosphorus is detrimental for the same reason.—V. G.

New Mold Coatings. H. J. Walker. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 75–76). Tar has proved to be the most suitable material for mould coatings as opposed to powdered pitch; graphite; aluminium powder suspended in water, molasses, or in a rosin-base solvent; salt water; powdered sugar; fuel oil; and petroleum residue. A mould-coating machine is better than hand-spraying.—F. C.

Practical Interpretation of Steelmaking. C. F. Christopher. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 313–327). The deoxidation of steel with Si or Al, the types of inclusion formed as a function of the thoroughness of deoxidation, the temperature at which deoxidation occurs, and the carbon content of the steel are considered.—F. C.

Effect of Aluminium Content on Internal Quality of a Killed Steel. V. E. Elliott and N. D. Fragasse. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 131–127). An abnormal etch pattern observed in large blooms of 0·7% carbon steel is described. This pattern was associated with grain-boundary sulphide inclusions thought to be due to the aluminium addition of 1·2 lb./ton for grain-size control. A smaller addition (0·9–1·0 lb./ton) greatly lessened the frequency of occurrence and severity of this pattern. Other investigators have found that a critical range of aluminium addition exists in which grain-boundary inclusions occur with random inclusions forming when the aluminium is above or below this critical range. Small changes in iron oxide content and the formation of aluminium sulphide probably affect this change in solubility. The hydrogen content also probably influences the formation of grain-boundary inclusions in this steel.—F. C.

PRODUCTION OF FERRO-ALLOYS

Recent Developments in the Manufacture of Electrolytic Manganese. Ch. Tschappat. (*Chim. e Ind.*, 1951, **33**, June, 333–339). [In Italian]. The properties of pure manganese are discussed. Manganese may now be considered almost as a new metal destined to modify established metallurgical methods. Manganese alloys, depending on the constituents, may be sound-proof and have low thermal conductivity. Its hardness can range from that of copper to the hardest tool steel. The author shows how manganese steels (15–20% Mn) which have hitherto been considered practicably unworkable may become ductile if the manganese is produced electrolytically. New methods of preparation are being explored to make use of low-grade minerals with poor manganese content which cannot be reduced economically by the customary thermal methods. Reference is made to the first successful attempt to produce electrolytic manganese in the U.S.A., and to the work now going on in Europe to render economically utilizable the considerable quantities of low-manganese minerals available in Western Europe by making use of the large resources of electric energy.—M. D. J. .B.

General Considerations on the Use of Ferro-Alloys in France. Ch. Dingeon. (*J. Four Elect.*, 1951, **60**, July–Aug., 85–89). A report of a conference which discussed the visit of the French electro-metallurgical productivity team to the U.S.A. is given. The improvements in physical properties of steel by addition of alloying elements and the mechanism of the process are discussed. The American vacuum methods of preparing metals pure enough to be malleable are reported. Notes on the recent production of pure metallic titanium on an industrial scale are given.—B. G. B.

Chromite Investigations. Part I—A Critical Review of Methods of Utilization with Special Reference to Transvaal Ores. I. H. Kahn and A. M. Schady. (*J. Chem. Met. Min. Soc. S. Africa*, 1951, **51**, Feb., 247–260). The uses of chromite and the characteristics of the Transvaal ores are surveyed. They are unsuitable for the manufacture of refractories, and without some sort of beneficiation will not find a ready market as metallurgical-grade chromite. Possible methods of chemical processing, and methods for the direct use of the arc as such for the production of ferrochromium are briefly indicated.

FOUNDRY PRACTICE

Using Foundry "Spec" Sheets. J. Taylor. (*Canad. Metals*, 1951, **14**, June, 22, 24–26, 28). Specification sheets are described as essential to profitable foundry operation. They improve efficiency and save time by serving as a guide for repeat orders, particularly in moulding and core-making. Reliable cost estimates can be made with them.—E. C.

Desulphurization in the Cupola and Electric Furnace. C. W. Pfannenschmidt. (*Giesserei*, 1951, **38**, Sept. 20, 459–469). Available facilities for reducing the sulphur content of iron are considered. The composition of the cupola lining can be adjusted, and the slag basicity can be controlled by adding calcium and manganese carriers. Improved desulphurization of molten cast iron with caustic soda and soda ash is possible, particularly by scavenging the bath with an appropriate slag mixture. A method employing a double-siphon ladle has been developed for large-scale production.—J. G. W.

Cupola Practice at the Stanley Works. R. L. Baldwin. (*Amer. Inst. Min. Met. Eng., Proc.* 1950 *Open Hearth Conf.*, **33**, 108–110). Two cupolas of 54-in. inside dia. supply 40% of the charge as hot metal for three basic open-hearth furnaces at the Stanley Works, Bridgeport, Conn. The cupolas operate on a continuous basis with a 35% cast-iron scrap and 65% steel scrap charge and produce 10–12 net tons/hr. with an average molten iron yield of 95% and an average analysis of C 3·0%, Mn 0·40%, P 0·22%, S 0·170%, and Si 0·65%. Desulphurization is with soda ash. With cupola hot metal the time per heat has been reduced by 15–20%.—F. C.

Development of and Experience with Hot-Blast Cupolas. K. Roesch. (*Giesserei*, 1951, **38**, Aug. 23, 393–397). Hot-blast cupolas find increasing application in malleable and grey iron foundries for high-quality castings. The recuperator serving two adjacent, alternately operated furnaces, which is finding favour is described. For small furnaces blast heaters are preferred on account of their robustness and cheapness. The hot-blast cupola described by O. Mattern is discussed (*see J. Iron Steel Inst.*, 1950, **165**, May, 110). Details of a new type are given; in this, hot gases are bled off under their own pressure at about 1 m. above the tuyeres, passed through a dust catcher and burnt with high-velocity hot air in a small combustion chamber, the fully burnt gases are then drawn through the blast heater which is made of small cast-iron pipes with very smooth internal and external surfaces. Data on output, efficiency, optimum blast temperature, metallurgical behaviour and costs of several types of installation are given.—R. A. R.

Structural Aspects of Tellurium and Graphite Additions for Chill Control in Cast Iron. E. A. Loria. (*Foundry*, 1951, **79**, June, 126–129, 212–218). Additions of tellurium and graphite in balanced proportions to a normal chilled-iron composition produce a casting with a white iron, wear-resistant surface backed by a narrow zone of finely dispersed mottled iron. Thus it is possible to produce a hard surface on an iron casting with the use of a chill. The form tellurium in small amounts takes in castings is in doubt; no metallographic evidence of a telluride has been observed. A metallographic study is made of castings with different additions.—E. J. D. S.

On the Stepped Heat-Treatment of Cast Iron. U. v. Hummel and E. Piwowarsky. (*Giesserei, Technisch-Wissenschaftliche Beihefte* 5, 1951, Sept., 219–230). After a survey of American literature, the authors describe their own experiments with four cast irons, one without alloying additions, one with a small amount of nickel, and two Ni–Mo cast irons of which one was treated to obtain nodular graphite. **S**-curves over the range 200–400° C. were determined and with their aid bainitic structures were obtained. The heat-treatment produced a 50% increase in the ultimate tensile stress, and doubled the impact strength. These results were obtained with test pieces 12 mm. thick; the mass effect remains to be explored.—J. G. W.

Cast Camshafts. (*Automobile Eng.*, 1950, **40**, Sept.–Oct. 345–347). The development, casting, and service properties of cast-iron camshafts by the Midland Motor Cylinder Co., Ltd., Smethwick, are described. The high-duty cast iron used for these is Monikrom (C 3·10–3·40, Si 2·00–2·40, S 0·100 max., P 0·200 max., Mn 0·50–0·080, Ni 0·15–0·25, Cr 0·80–1·00, Mo 0·15–0·25%; modulus of rupture 36 tons/sq. in.; Brinell hardness 240–280).—R. A. R.

Critical Considerations on the Mechanism of Formation of Nodular Graphite. J. de Vidts and A. de Sy. (*Rev. Mét.*, 1951, **48**, July, 547–551). Evidence suggesting a germination mechanism is reviewed and further work by the authors described.—A. G.

Producing Malleable Cast Iron. L. R. Friedman. (*Amer. Foundryman*, 1950, **18**, Oct., 39–41). The choice and quality of raw materials for making white iron for malleable iron castings and the melting technique are discussed. The effects of the CO/CO_2 ratio and N_2 atmospheres on graphitization and the functions of alloying additions which promote or retard graphitization are reviewed. Melting practice, not annealing, will do most to determine the final characteristics of the metal.—E. J. D. S.

Characteristics, Limitations and Applications of Malleable Iron Castings. H. A. Schwartz. (*Malleable Founders' Soc.: Foundry*, 1951, **79**, May, 102–103, 236–239). Applications of malleable castings and properties necessary to meet them are discussed.—E. J. D. S.

Equipment and Methods of Straightening and Dimensional Inspection of Malleable Iron Castings. L. N. Schuman. (*Amer. Foundrymen's Soc.*, 1951, Preprint No. 31). The

development of straightening and inspection methods is briefly traced. The proving method for samples is discussed. Straightening is carried out in conventional hydraulic presses of 500 to 1000 tons capacity with an output of 300 to 500/hr.—P. C. P.

Defects in Steel Castings. G. Ferrero and G. Ziliani. (*Met. Ital.*, 1951, **43**, Aug., 323–332). The authors distinguish between defects due to metallurgical causes and to moulding technique and review frequently occurring defects.—M. D. J. B.

Steelmaking for Castings. J. H. Hall. (*Foundry*, 1951, **79**, Mar., 98–99, 228–233; Apr., 128–129, 263–271; May, 101, 222–229; June, 109, 232–240; July, 77, 232–241). This series of articles provides a general descriptive introduction to acid and basic open-hearth furnace operation, melting and pouring practice, composition of the charge, and refractories and their installation.—E. J. D. S.

Olivine Sand Research. G. S. Schaller and W. A. Snyder (*Foundry*, 1951, **79**, May, 104–105, 168, 170). A research programme for olivine as a moulding material is discussed.

Metal Penetration. S. L. Gertsman. (*Foundry*, 1951, **79**, May, pp. 84–89). **Evaluate Metal Penetration Variables.** S. L. Gertsman. (*Amer. Foundryman*, 1951, **19**, Apr., 94–99). A study of metal penetration into sand moulds and cores is reported. The following recommendations are made: (1) Use low pouring temperatures consistent with fluidity; (2) ram well, but over-ramming does not help in resisting penetration; (3) use fine-grained sands or make silica flour additions to cores; and (4) use washes which will not crack under thermal shock.—E. J. D. S.

Metal Penetration Test. S. L. Gertsman and A. E. Murton. (*Amer. Foundryman*, 1951, **19**, Mar., 32–33: *Amer. Foundrymen's Soc.*, 1951, Preprint No. 16). The test described has been approved by the American Foundrymen's Society, Sand Division, as a tentative standard test. A casting is made 6 in. in dia. at the top and 5⅞ in. in dia. at the bottom, the height depending on the ferrostatic pressure required on four test cores placed round the ingate. The relative resistance of these cores to metal penetration, all of which may be of different sand mixtures, may be measured by visual examination or by a microscope of low magnification.—E. J. D. S.

Scab Defect on Gray Iron Castings. Amer. Foundrymen's Soc. Committee on Physical Properties of Iron Moulding Materials at Elevated Temperatures. (*Amer. Foundrymen's Soc. Preprint No.* 23, 1951). Tests on a large number of sands are described. The scabbed areas of the test casting were measured by pressing aluminium foil over the defective areas and trimming around the edges. The area of the scab was calculated from the weight of the aluminium foil. It was found that: (*a*) Sands deforming 0·009 in. or more at 1000° F. did not produce scabs; (*b*) most of the scabbing sands had a green strength below 10 lb./sq. in.; (*c*) non-scabbing sands had a density below 110 lb./cu. ft.; (*d*) most non-scabbing sands had green deformation values below 0·021 in./in.; (*e*) permeability should be over 50; (*f*) dry strengths over 150 lb./sq. in. were associated with scabbing sands.—P. C. P.

The Siliceous Sands of Torre del Lago and Their Use in Foundries. G. Somigli and A. Catelani. (*Met. Ital.*, 1951, **43**, July, 281–295). This paper describes the siliceous sand deposits of Torre del Lago, their geological origins, and the methods of extracting them.—M. D. J. B.

Rational Analysis of Foundry Clay Sands. E. Zan. (*Met. Ital.*, 1951, **43**, Aug., 337–338). A national method of testing foundry clay sands is given and its advantages are pointed out.—M. D. J. B.

Design of Coreboxes and Driers for Use on Core Blowers. E. Blake. (*Foundry*, 1951, **79**, June, 114–117, 260–264). The design and efficient use of core boxes and driers are discussed.

Core Oil Evaluation Method. A. E. Murton, H. H. Fairfield, and B. Richardson. (*Amer. Foundryman*, 1951, **19**, Apr., 85–89). The strength of cores made from the same oil and sand under the same conditions varies. This variation was reduced by maintaining the baking temperatures within ±2° F. Storage of cores in a highly humid atmosphere lowers the baked tensile strength, but this is revived by redrying the cores at 220° F. Core oven humidity increases the baking time required.—E. J. D. S.

Aspects of Continuous Casting. D. R. Wood. (*J. B'ham. Met. Soc.*, 1951, **31**, Mar., 25–30). The author considers the thermal equilibrium in the open-mould continuous casting process and examines conditions under which various metals and alloys may be cast by such a method. The heat contents and thermal diffusivities of magnesium, aluminium, copper, nickel, and iron are compared.—R. A. R.

Investment Casting. B. G. Mackenzie. (*Canad. Metals*, 1951, **14**, June, 20–21). An outline is given of the investment casting of machine components, using high-quality non-machinable alloys. Its advantages are stated.—E. C.

Special Investment Casting Techniques. K. J. Yonker and G. A. Stolze. (*Amer. Foundryman*, 1950, **18**, Oct., 33–36). Factors influencing the production of complicated investment castings are discussed with special reference to technique, using stator discs, compressor blades, and rotors as examples.

Centrifugal Casting. C. Englisch. (*Giesserei*, 1951, **38**, Aug. 9, 369–373). Various centrifugal casting methods are described and their advantages over gravity casting are summarized. The connection between the presence of slag and oxides in the interior of the casting and incorrect rotational speed is pointed out. The behaviour of different metals when cast centrifugally and mould design is discussed.—J. G. W.

Centrifugal Casting in Permanent Molds. W. F. Wilson. (*Product Eng.*, 1950, **21**, Nov., 112–116). The centrifugal casting process is being used for alloys capable of withstanding the conditions imposed in aircraft gas turbines. The advantages of this method and the design factors which have to be considered are discussed. Castings weighing more than 500 lb. can be made. Pieces over 8 in. in dia. compare favourably in cost with forged or rolled tubing.—A. M. F.

Lufkin Gray Iron Foundry Serves Industrial Southwest. W. G. Gude. (*Foundry*, 1951, **79**, May, 90–93, 165–166, 168). A review of the foundry practice, layout, and products of the Lufkin Foundry and Machine Co. of America is presented.—E. J. D. S.

Steel Foundry Progress: Reorganization by Osborn Foundry & Engineering Co. (*Iron Steel*, 1951, **24**, July, 327–330; Aug., 382–386; Sept., 417–419, 422). Reorganization of the steel foundry of the Osborn Foundry and Engineering Co., the principles behind it, and the progress made are described.

Fluidity and Solidification Tests for Molten Steels. W. Ruff. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 21–25). [This issue].

Interference with Crystallization Processes and a Method for Refining Graphite in Grey Cast Iron. W. Rauterkus. (*Giesserei, Special Issue No.* 5, 1951, Sept., 211–218). The theory of nucleation in the solidification of metals and alloys is explained and the findings are brought to bear on the problem of nodular graphite formation in cast iron. Graphite refining was obtained by aluminium nitride nucleation and the method, when applied to crankshaft alloys, produced a 35% improvement in properties, particularly the torsional fatigue strength.—J. G. W.

On the Crystallization of Metal Melts. E. Scheil. (*Giesserei, Special Issue No.* 5, 1951, Sept., 201–210). New experimental and theoretical findings concerning rate of crystallization and nucleation are discussed. Nucleation is compared with heterogeneous catalysis, whence is derived the important concept of 'poisoning' the nuclei by adsorbed impurities. The formation of grains in casting is discussed and means of influencing it are considered.—J. G. W.

Investigations of the Mottled Appearance of Pig and Cast Iron. K. Krämer. (*Giesserei, Technisch-Wissenschaftliche Beihefte* 5, 1951, Sept., 231–236). The author demonstrates that the mottled appearance of cast iron is caused by undercooling which, after the primary graphite has crystallized, inhibits the normal crystallization of the graphite eutectic and leads to the formation of pseudo-primary γ solid solution together with undercooled eutectic. This undercooling can only take place in hypereutectic pig or cast irons which solidify as grey irons. The author produced mottling in a cast which had no steel additions by increasing the proportion of blast-furnace ferro-silicon or by the addition of silicon cast iron.

J. G. W.

Wetting Agents Useful in the Foundry. P. Winters. (*Foundry*, 1951, **79**, June, 118–121). The use of water containing a wetting agent to reduce dust in foundries is described. It is effective and inexpensive. It is best to spray it in mist form on floors and into dust-laden atmospheres.—E. J. D. S.

Foundry Dressing Operations: Control of Dust. R. F. Ottignon. (Inst. Brit. Found.: *Iron Steel*, 1951, **24**, Aug., 389–392). The author considers three methods of protecting the dresser of steel castings from dust, namely, wearing respirators, general ventilation to reduce dust counts, and local exhaust at the point of origin. The last factor appears to be the only practical measure, and the author describes in detail

an experimental fettling bench which is being tested. By directing a small percentage of the exhaust air back across the working position of the bench, it is possible to keep 90% of the dust away from the operator, with an expenditure of about 0·4 h.p. per bench.—G. F.

Development of Foundry Courses in High and Trade Schools. R. W. Schroeder. (*Amer. Foundrymen's Soc.*, 1951, Preprint No. 39). The relationship between the American foundry industry and the local school is discussed and the course at Tennessee Agricultural and Industrial College is outlined.

HEATING FURNACES AND SOAKING PITS

Steel Quality as Affected by Track Time and Soaking Pit Practice. A. F. Mohri. (*Amer. Iron Steel Inst.*, May 23–24, 1951, Preprint: *Indust. Heating*, 1951, **18**, July, 1217–1218; Aug., 1405–1414; *Blast Furn. Steel Plant*, 1951, **39**, June, 665–670). The author describes the melting shops, mould-handling schemes, and soaking-pit practice at the Hamilton Works of the Steel Company of Canada Ltd., and discusses in particular the effect of track time and soaking treatment on the steel quality. The specification of minima and maxima for track times and for the heating and soaking of the ingot will assist in controlling the quality of the finished product, and will reduce billet dressing to a minimum.—G. F.

High-Frequency Heating of Forging Billets. (*Metal Progress*, 1951, **60**, July, 70–73). This is a description of a new type of heater installed by a British firm. The advantages of high-frequency heating are cleanliness, quick warming up of the furnace, and less overall cost than oil-fired furnaces.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Fundamentals and Practice of Heat-Treating Cast Steel. H. Juretzek. (*Giesserei, Technisch-Wissenschaftliche Beihefte* 5, 1951, Sept., 237–248). The author explains the formation of the primary and secondary structures, and normalizing, spheroidizing, and stress-relieving treatments applicable to high carbon cast alloy steel. Recent findings in the kinetics of steel transformation, hardenability, and the Jominy test are discussed. The influence of the quench temperature in the heat-treatment of 12% Mn austenitic cast steel was studied.

Heating and Cooling in Steel Treatment. J. Lomàs. (*Brit. Steelmaker*, 1951, **17**, Sept., 475–478). The author describes the structural transformations which take place in heating and cooling, and discusses the characteristic results obtained in relation to the varying temperature changes and the mass of the piece involved.—G. F.

Tool Steel: Manipulation and Heat Treatment. A. J. Blackwell. (*Iron Steel*, 1951, **24**, July, 355–358; Aug., 387–388). The melting processes and main factors influencing the production of sound ingots of high-speed steel including casting temperature, mould proportions, and size of ingot cross-section are considered. Heat-treatment of the ingot and procedures for cooling, annealing, and reheating for forging are described. Finally, the forging operation is dealt with. The importance of obtaining uniformly distributed carbide particles is emphasized.—G. F.

Some Particular Questions on the Modern Heat-Treatment of Steels. A. Michel. (*Rev. Univ. Min.*, 1951, **7**, Sept., 281–293). A detailed examination of the isothermal and anisothermal transformation curves of austenite is made with graphs showing the stabilization of austenite by ageing.

A Study of Cementation Reactions in Thin Films of Iron. J. J. Trillat and S. Okétani. (*Métaux-Corrosion-Indust.*, 1951, Apr., 145–152). An electron microscope was used to study the effects of heating a thin film of iron in a stream of pure CO or of CO + H_2. The results indicated that when hydrogen was present and at temperatures of 300–400° C., a percarbide Fe_2C was formed after some time. Two possible mechanisms are suggested, either (1) Fe_3C is formed intermediately, and the hydrogen assists the reaction by removing the CO_2 produced, thus improving the rate of gaseous diffusion; or (2) the hydrogen is adsorbed on the iron crystals, and then reduces the CO with deposition of carbon.—N. McE.

The Heat-Treatment of 3% Nickel–Chromium Case-Hardening Steel. H. D. Mansion. (*Metallurgia*, 1951, **44**, Aug., 57–62). To furnish information for the heat-treatment of test gears, two samples of En 36 Ni–Cr case-hardening steel were given various heat-treatments. Small test bars, all carburized as one batch, were given single and double quenching treatments and a stress-relieving treatment, the hardness and metallurgical structures being studied at each stage. The main effect of the first quench is to diffuse the cementite network of the carburized case, the core structure and strength being little affected as compared with those of single-quenched specimens.—J. B. B.

Oldsmobile Axle Shafts Are Heat-Treated Automatically. (*Indust. Heating*, 1951, **18**, Apr., 598–606). A description is given of a completely automatic installation for production hardening of rear-axle shafts, The unit consists of a Holcroft heating furnace, quench tank, and tempering furnace; it is designed to process 215 axle shafts per hr.—J. A. L.

Automotive Gear Steels—How Industry Selects and Heat-Treats Them. V. E. Hense, H. H. Miller, and R. B. Schenck. (*S.A.E. J.*, 1951, **58**, Oct., 25–29).

Large Scale Production Heat-Treatment at the Standard Motor Co., Ltd., Banner Lane Works, Coventry. L. H. Williams. (*Metal Treatment and Drop Forg.*, 1951, **18**, June, 257–269, 271). A description is given of heat-treatment practice at the Coventry factory of the Standard Motor Co. Ltd. Plant layout, photographs, and full descriptions are given of the annealing and normalizing of raw materials, the heat-treatment of rear-axle shafts, pack and gas carburizing, and cyanide hardening.—P. M. C.

Pearlitic Malleable Irons Can be Successfully Surface Hardened. S. H. Bush, F. B. Rote, and W. P. Wood. (*Mat. Methods*, 1951, **33**, Apr., 70–72). When a hard, wear-resistant surface, produced by flame or induction hardening, is added to the other desirable properties of pearlitic malleable castings, the number of possible applications is greatly increased. Cases averaging Rockwell C 60–62 on the surface, and of any desired depth, can be produced by both the above methods. Details of recommended treatments are given.—P. M. C.

Heat-Treatment of Steel by Means of Gas-Oxygen Flames without Furnaces. H. Bühler. (*Z.V.d.I.*, 1951, **93**, Aug. 21, 756–758). The advantage of flame heat-treatment lies in the possibility of fitting it into the sequence of manufacturing operations with a minimum of handling. Improved deep-hardening and annealing of large parts with the oxygen/town-gas flame were obtained by: (1) Increasing the distances between torch and spray; (2) oscillating the burner; and (3) preheating the part.—J. G. W.

Flame-Hardening by the Rotation Method and the Influence of Heating Conditions and Size of Piece on Time and Depth of Hardness. A. Matting and H. W. Grönegress. (*Schweissen u. Schneiden*, 1951, **3**, Aug., 238–242). A maximum depth of hardness of 3 mm. was obtained with flames 20 to 80 mm. in dia. An increase in gas flow rate from the burner from 100 to 140 m./sec. with single burners resulted in a decrease in hardening time. A higher temperature gave a greater depth and a linear relationship exists between time and depth of hardness.—U. E.

Gear Hardener Loads and Unloads Automatically. P. Good. (*Iron Age*, 1951, **167**, Mar. 22, 72–74). A brief description is given of a new induction hardening machine for contour or through hardening of gears ranging from 2½ to 8¼ in. pitch dia.

Gaseous Nitriding. A. Morgan. (Australian Inst. Met.: *Australasian Eng.*, 1951, June 7, 82–89). This paper deals with the gaseous nitriding of the steels commonly nitrided in Australia. The mechanism of nitriding is explained. The composition of the various grades of Nitralloy are discussed, and the processing techniques required for preparing the material for nitriding are outlined. The nitriding process itself is then described, and limitations to the use of nitrided Nitralloy are indicated.—P. M. C.

Investigations into the Carbonitriding of Plain Carbon Steel. H. C. Fiedler, M. B. Bever, and C. F. Floe. (*Amer. Soc. Metals*, Oct., 1951, Preprint No. 7). The effectiveness in the carbonitriding process of (*a*) interruption of the ammonia flow, (*b*) cooling to subatmospheric temperatures, and (*c*) multiple cooling was measured. Carbon steels give harder cases than alloy steels but are not so good in the core.

A Method of Simulating the Oil Cooling of Steel Bars. A. Steven and G. Mayer. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 370–376). Cooling curves determined from temperature measurements taken at several positions in bars of up to 5¾ in. in dia. quenched in oil have been compared with the air-cooling curves of bars up to 0·8 in. in dia. The cooling of a 1–6-in. dia. oil-quenched bar, over the temperature range within which transformation to structures other than marten-

site is likely to occur, can be closely simulated by air-cooling a bar of approximate size between 0·052 and 0·890 in. in dia. A close equivalence relationship has been established between the cooling curves of bars quenched in oil and the cooling curves derived at points along the length of an end-quench Jominy test specimen, based on a comparison of the curves at temperatures in the transformation range below about 700° C. The experimentally determined cooling curves were not in good agreement with curves calculated from the tables published by Russell, but the differences between the cooling curves for the axial and near-surface positions of 2–6-in. dia. bars cooled in air agreed, over the temperature range 800–500° C., with the 'time-lag' equation used by Jackson and his collaborators.

High Speed Quenching Oils Increase Surface Hardness. W. J. Reitze. (*Steel*, 1951, **128**, June 18, 72–74). The three phases encountered in oil quenching are explained, and the desirable properties of quenching media are reviewed. These should have the characteristics of water during the vapour blanket stage, characteristics intermediate between water and oil during the second stage and the characteristics of straight mineral oil in the third stage, also a high boiling point, low viscosity, and high flash and fire points (345° F.). The use of water for quenching and the relative merits of hot and cold oil quenching are discussed.—M. D. J. B.

Quenching of Steels by Cooling in Liquids and the Work of H. Le Chatélier. A. Portevin. (*Rev. Mét.*, 1951, **48**, July, 497–504). A study of quenching must include the physico-chemical phenomenon of austenite decomposition, the properties resulting from thermal heterogeneity, and the chemical reactions at the surface during heating and cooling. The work of H. Le Chatélier on (*a*) cooling by liquids and (*b*) industrial problems of quenching steels is described.—A. G.

FORGING, STAMPING, DRAWING, AND PRESSING

New Device Increases Hammer's Operational Flexibility. (*Steel*, 1951, **128**, June 18, 80). A new short stroke control device developed for the Chambersburg Ceco drop hammer is described. This air-operated mechanism enables the operator of the gravity drop hammer to select either a long or short stroke at will—M. D. J. B.

18,000-Ton Hydraulic Forging Press Housed in Massachusetts Plant. G. W. Motherwell. (*S.A.E. J.*, 1950, **58**, Aug, 70–72). Brief details of this press and its erection at the Grafton plant of Wyman-Gordon Co. are given.—R. A. R.

Forging Clutch Pedals at Dodge Plant. J. C. McComb. (*Steel Processing*, 1951, **37**, June, 273–275). The production of clutch and brake pedals at the Dodge Forge Plant of the Chrysler Corp., U.S.A., is briefly described and illustrated. These are made at 250/hr. on a 2000-ton high-speed forging press used in conjunction with a forging roll, whilst 157/hr. are produced on a 3000-lb. steam hammer and a 2-in. upsetter.

Oil Seal Manufacturer Cuts Drilling Time by Using Hollow Die Steel. R. S. McGranahan. (*Western Metals*, 1951, **9**, July, 36, 37). The author discusses the saving of material, time, and money by using hollow instead of solid bar stock to make ring-shaped dies.—P. M. C.

Precision Bending Dies. F. Strasser. (*Steel Processing*, 1951, **37**, June, 276, 277). The production of 90° bends in sheet metal is briefly discussed, with a note on the correction of 'springback.'—P. M. C.

A New Approach in the Preparation of Forging Blanks. H. E. Hows. (*Metal Treatment and Drop Forg.*, 1951, **18**, June, 274–278). The range of forging blanks made available by preforming methods has been widened by roll-forming machines. The author gives particulars and advantages of a modern machine, the 'Reduceroll,' which is manufactured by the National Machinery Company, U.S.A.—P. M. C.

Inspection of Drop Forgings from a Metallurgical Standpoint. R. J. Brown. (*Metal Treatment and Drop Forg.*, 1951, **18**, July, 312–315). The author gives his views on the relative and complementary positions in a drop-forging establishment of the works inspector and the works metallurgist. Routine inspection of materials is discussed from a metallurgical standpoint.—P. M. C.

Regulator Parts Mass-Produced in Progressive Dies. A. Ensign. (*Iron Age*, 1951, **167**, Mar. 15, 114–116). The Ford Motor Co., Ypsilanti, Mich., employ a Brandes die press for producing base stampings for voltage regulators. A production rate of 40 units/min. is obtained with a five-station progressive die. A 'Multislide' machine is producing other stampings from 0·090-in. stock at 46 units/min. in a three-station die.—A. M. F.

An Experimental Crank Press. E. C. Seed and H. W. Swift. (*Proc. Inst. Mech. Eng.*, 1950, **163**, W.E.P. No. 58, 125–134). An account is given of the technical problems which arose in designing an experimental single-action, double-sided crank press for use in deep-drawing research in the University of Sheffield.—R. A. R.

Cold Forming of Low Carbon Steel. L. F. Spencer. (*Steel Processing*, 1951, **37**, Mar., 128–131, 153; Apr., 184–187; May, 232–234; June, 280–283). This series of articles covers the qualities of steel suitable for cold forming; grades of sheets for drawing and their hardness and surface finish; grain size; detrimental effects of segregation; ageing and elimination of stretcher strains; evaluation of drawability; technique for cylindrical cup drawing; cupping tests; and the Marform process which combines a steel punch with a rubber backing pad. Single, double, and triple action presses are described. (27 references).—R. A. R.

Mechanical Fabrication of Thin Sheet. R. Dupas. (*Mét. Constr. Méchan.*, 1951, **83**, June, 463–465). The difficulties involved in stamping, cambering, cutting, and punching are discussed.—R. S.

Lockheed's 8000-Ton Hydraulic Press Requires Unusual Transportation and Erection Methods. G. A. Blackman. (*Western Metals*, 1951, **9**, Aug., 28, 29). A brief account is given of the road and rail transportation and the erection of an 8000-ton hydraulic drawing and blanking press. The bed and crown each weigh 160 tons.—P. M. C.

Aircraft Propellors: Hot Extrusion of Seamless, Hollow Steel Blades, A. I. Nussbaum. (*Iron Steel*,1951, **24**, Aug., 380–381). The Curtiss-Wright Corporation, New Jersey, has developed a new method of fabricating seamless hollow steel propeller blades which involves the hot extrusion of a billet of Cr–Ni–Mo steel to form a blade up to 10 ft. in length. The process is described.—G. F.

Cold Extrusion of Steel—Effect of Lubricants, Tool Contours and Reductions. H. Hauttmann and W. M. Baldwin, jun. (*Iron Age*, 1951, **167**, Mar. 15, 99–104). This is a translation of an article by H. Hauttmann in *Arch. Eisenhüttenw.*, 1950, **21**, July–Aug., 235–242 (*see J. Iron Steel Inst.*, 1951, **168**, May, 101).

Advantages of Cold-Drawn Pinions. E. H. Rathbone. (*Product Eng.*, 1950, **21**, Dec., 114–116). Comparisons are drawn between pinions made by extrusion, cutting, and cold drawing. The outstanding properties of the last are the desirable compressive stresses in the teeth, the smooth hardened surface, and the dimensional accuracy attained.

Contribution to the Applied Mechanics of Deep Drawing. H. Kostron. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 205–213). Deep drawing of a cylinder from a circular annulus is considered theoretically, first on the assumption that the sheet thickness remains constant, then on the assumption that no strain results in the radial co-ordinate of the annulus on drawing. The stress/strain curve is assumed to be parabolic, and the maximum shear-stress criterion is taken to be valid for yielding. On this basis the stress distribution at any instant during drawing is determined. The theory shows that in actual drawing a decrease in the wall thickness of the cylinder is initially to be expected, but that at a certain stage, determined by the work-hardening index of the stress/strain parabola, the wall thickness begins to increase. The more rapidly the metal work-hardens, the sooner is this stage reached.—P. F.

Examination of a New Method of Hot Deep-Drawing. D. Lenz. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 215–224). Deep-drawing dies, developed at the Vereinigte Leichtmetall-Werke, are described and their performance is examined. For drawing cylindrical cups from aluminium and aluminium-alloy flats, the central portion of the die and the plunger are water-cooled, while the edge of the die, and the portion of the flat which is about to enter the die, are heated. The metal is thus plastic in the flow zone.—P. F.

A Theory of Tube Sinking. S. Y. Chung and H. W. Swift. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 29–36). [This issue].

Wire Drawing on Multi-Stage Drawing Machines. M. Schneider. (*Prace Badawcze Glownego Inst. Met.*, 1951, No. 3, 233–239). [In Polish]. The theoretical basis of multi-stage wire drawing is discussed. Formulæ for calculating drawing forces are derived which take into account the friction, plastic strength, and plastic resistance. It is shown that

when a back-pull tension is applied, friction in a die is diminished. On the basis of the relationship between peripheric speed of drawing rings, wire diameter, and number of ring rotations a formula is given for calculating the power requirements of multi-stage drawing machines. Formulæ for the quantity of heat generated in a die are also given.—V. G.

Wire Mill Practices at Republic Steel Corporation's Gadsden Plant. A. D. Gordon. (*Wire and Wire Products*, 1951, **26**, July, 568–570, 622). The main features of wire processing in this plant, where nails and fencing wire are made, are briefly described.—J. G. W.

New Developments in Adjustable Speed Drives for Wire and Cable Mills. G. Bevis. (*Wire and Wire Products*, 1951, **26**, Aug., 678–679, 696–708). A description of the V and S and other drives, is given. These drives contain an automatic, electronic speed and acceleration control, and are manufactured by Reliance Electric and Engineering (Canada) Co., Ltd., Montreal.—J. G. W.

Factors Affecting the Selection of Wire-Drawing Equipment. R. A. Duke. (*Wire and Wire Products*, 1951, **26**, Aug., 676–677, 692). The author classifies continuous wire-drawing machines as 'non-regulated' or 'regulated tandem' machines, the former being either of the 'slip' or 'accumulator' type. In 'non-regulated' machines block and wire speeds are not synchronized. In regulated machines synchronization is achieved either by motor speed control, or—more recently—by torque control.—J. G. W.

The Use of Basic Open-Hearth Semi-Killed Steels in the Manufacture of Wire Mill Products. K. P. Campbell. (*Wire and Wire Products*, 1951, **26**, July, 571–573, 618–619). Fine grades of semi-killed steels (C 0·05 to 0·22%) are used in the Houston, Texas, plant of the Sheffield Steel Corporation, to make fencing wire. In order to get maximum yield from ingot to bloom 23 × 25 in. moulds are poured to a height of 85 in., which yields two $8\frac{7}{8} \times 8\frac{7}{8}$ in. × 22 ft. blooms, with an average yield of 88·6% from ingot to bloom, of 99·2% from bloom to 2 × 2 in. billet, and of 94·8% from billet to 0·218 in. dia. rod. The high yields are ascribed to better rolling characteristics of the semi-killed, as opposed to rimming, steels.

J. G. W.

ROLLING-MILL PRACTICE

Margam and Abbey Works: Some Important Electrical Installations. (*Iron Steel*, 1951, **24**, Sept., 405–410, 439). The major electrical installations at the Margam and Abbey Works of the Steel Company of Wales Ltd. are described with particular reference to the motor drives of the rolling mills.

Requirements for a Modern Steel Mill Power Distribution System. F. H. Wickline. (*Iron Steel Eng.*, 1951, **28**, Aug., 77–81). This paper studies a 60-cycle distribution system installed to serve the new Lorain mills of the National Tube Co. and reveals certain principles that are applicable to all mill distribution systems.—M. D. J. B.

Continuous Cold Rolling of Thin Strip at the Montataire Works. (*Génie Civil*, 1951, **128**, May, 161–164). This rolling mill commenced operations in 1950. A description of the various stages, (continuous descaling, first rolling, reheating in a neutral atmosphere, and second rolling) is given.—A. G.

A Note on the Cold Rolling of Very Thin Strip. R. Hill and I. M. Longman. (*Sheet Metal Ind.*, 1951, **28**, Aug., 705, 706). It is known that in a single pass through a given mill, there is a minimum thickness that can be rolled to a given percentage reduction. The authors derive approximate formulæ which enable such minimum thicknesses to be calculated, but remark that the theory is only likely to be reliable for reductions less than 50%.—P. M. C.

Precision Rolling Thin-Gauge Magnetic Alloys. (*Steel*, 1951, **128**, June 25, 114). A description is given of a new Sendzimir cold strip mill for rolling magnetic alloys down to 0·0005 in. in width up to $8\frac{1}{2}$ in. This reversing mill, installed in the Naval Ordnance Laboratory at White Oak, Md., driven by five motors, has two small-diameter work rolls, four driven back-up rolls, and special back-up 'saddles,' and roller bearings.—M. D. J. B.

Washington Steel Corporation's 39-In. Cold Mill. T. S. Fitch. (*Iron Steel Eng.*, 1951, **28**, Aug., 51–56). The Sendzimir 39-in. mill of the Washington Steel Corp. for cold rolling of stainless steel is described. Data on speeds, production, outputs, and costs are given. Substantial savings are claimed as no intermediate annealing and pickling operations are required and because there is less handling.—M. D. J. B.

Principles of Continuous Gauge Control in Sheet- and Strip-Rolling. W. C. F. Hessenberg and R. B. Sims. (*Inst. Mech. Eng. Advance Copy*, Oct. 26, 1951). Longitudinal gauge variations in hot- and cold-rolled sheet and strip are caused mainly by elastic distortions of the mill in response to variations in the separating force between the rolls. A unique relationship exists between roll force and the thickness of the strip leaving the rolls. On this basis two new methods of automatic gauge control have been devised. They employ an electrical roll-force measuring element the output of which continuously adjusts either the position of the rolls or the tension applied to the strip.—R. A. R.

Kaiser Steel's New 86-Inch Hot Strip Mill. (*Western Metals*, 1951, **9**, June, 38, 39). **New 86-Inch Hot Strip Mill in Production on Pacific Coast.** (*Steel*, 1951, **128**, Apr. 16, 82–85). A brief description is given of a new mill installed by the Kaiser Steel Co. at Fontana, California. It rolls strip from 24 to 72 in. wide in gauges from 0·078 to 0·1875 in.—A. M. F.

Deformation, Roll Design Factors, and Cladding in the Pilger Process. W. Scheurer, P. Grüner and A. Pomp. (*Stahl u. Eisen*, 1951, **71**, July 19, 760–768). Development of the pilger tube rolling process is outlined and relevant literature is reviewed. Deformation in rolling has been studied on screws driven into holes drilled in the bloom before rolling. Elongation is increased and circumferential spreading, particularly noticeable at the outer wall of the tube, is reduced by suitably shaped rolls with a hyperbolic entry profile, closely related roll and tube diameters, increased length of the polishing part of the groove, angle of taper of 14–15°, and roll clearance of 6% of tube dia. Groove diameter should be 1·2 to 1·5% larger than the diameter of the finished tube. Bimetal and plated tubes can also be successfully manufactured in pilger mills.—A. G.

Cooling Beds for Bar Mills. W. Udall. (*J. Iron Steel Inst.*, 1951, **169**, Nov., 257–276). The paper reviews briefly the evolution of the merchant bar mill during the last 50 years. The present-day versions of this type of plant have been made possible by the development of the mechanical cooling bed. Several of the earlier and later types of cooling bed and bed mechanisms are described and factors governing their location and operation are discussed. Theoretical and practical observations relating to thermal treatment and cooling capacity are included, and suggestions are made regarding future development.

LUBRICANTS AND LUBRICATION

Graphite as a Lubricant. E. S. Glauch. (*Iron Steel Eng.*, 1951, **28**, Aug., 58–60). The physical properties, characteristics, and uses of graphite are briefly discussed. All grades of graphite are not suitable for lubrication. A metal surface coated with graphite takes oil and grease more easily. Graphite will withstand higher pressures and temperatures than oils and greases.—M. D. J. B.

Wetting Characteristics of Lubricating Aerosols. D. G. Faust. (*Product Eng.*, 1951, **22**, July, 131–134). This article describes the principles and advantages of lubricating by oil fogs. To obtain wetting it is shown that the particles of aerosol must be 2μ in dia. and attain a velocity of impingement of 700 ft./min. It is claimed that considerable savings and increase of production capacity have been realized with this lubrication.—M. D. J. B.

Radioactive Tracers Reveal Friction and Wear of Metals. J. T. Burwell and C. O. Strang. (*Metal Progress*, 1951, **60**, Sept., 69–74). Experiments are described where the presence of radioactivity is examined on a surface after it has been rubbed on another and on radioactive material. The effects of lubrication, surface hardness, and material composition have been studied.—E. T. L.

Centralized System for Shears. (*Sci. Lub.*, 1951, **3**, Jan., 24–25). A centralized grease lubricating system for a large plate shearing machine is described.—R. A. R.

Proper Lubrication Lengthens Wire Rope Life. J. P. Critchlow and R. W. Flynn. (*Steel*, 1951, **128**, June 25, 110–112, 132). After briefly describing the complex nature of wire rope, the authors stress the importance for careful lubrication of wires and strands. Lubricants and methods of lubrication are considered. Fatigue and corrosion tests on fully, partially, and unlubricated wire rope are described and the results discussed.—M. D. J. B.

WELDING AND FLAME-CUTTING

The Development and Modern Application of the Metallic Arc Welding Process. G. Cubitt-Smith. (*J. Inst. Prod. Eng.*, 1951, **30**, Jan., 29–44). The history of the metallic arc welding process, including automatic processes is outlined. The following metallurgical considerations in welding are discussed: Structural transformations, size of austenite crystals, size and amount of inclusions, residual stresses, and effect of alloys and heat distribution during welding.—J. B. B.

Welding Practice in Britain. C. G. Bainbridge. (*Canad. Metals*, 1951, **14**, June, 34–36, 38, 46–47). An account is given of progress and present techniques in British welding practice as applied to shipbuilding, structural steel, and locomotive construction.—E. C.

Investigation of Welding with Deep-Penetrating Electrodes. A. Buchholz. (*Schweissen u. Schneiden*, 1951, **3**, Aug., 233–237). High-tensile ½-in. steel plates were welded with 'deep-penetrating' electrodes 3·25–5·0 mm. in dia. Sound welded deposits were obtained. Macro- and micrographs are given of the weld deposits.—U. E.

New French Standards Relating to Arc Welding Apparatus. A. Gaubert. (*Génie Civil*, 1951, **128**, Aug. 1, 290–292). Of six recent standards relating to welding, A85.011 which deals with technical regulations is discussed.—A. G.

Basic Electrodes for Welding Non-Alloy Steels. G. Zoethout. (*Lastechn.*, 1951, **17**, July, 97–101; Aug., 113–117; Sept., 126–129). [In Dutch]. The development and improvement of coated electrodes is traced and the reasons for using a basic electrode are explained. Gas contents and structures of the weld metal from Ferri-mantle, gas-shielded, and basic electrodes are compared. Finally, the mechanical properties of basic welding rods are discussed.—R. S.

A New Electrode Holder for Electric Arc-Welding. B. G. Filippov. (*Avtog. Delo*, 1948, No. 8, 28). [In Russian]. Drawings are given of a new electrode holder.—S. K.

Methods for Investigating the Technological Properties of Electrodes. A. A. Erokhin. (*Avtog. Delo*, 1948, No. 8, 12–16). [In Russian]. The properties of a coated welding electrode are listed, including such effects as: Ionizing action, the nature of the transfer of metal through the arc, efficiency of metal deposition, extent of splashing, and penetration. Methods for determining these properties were investigated.

Determination of Losses in Transformer Windings of Resistance Welding Machines. I. E. Futer. (*Avtog. Delo*, 1948, No. 8, 23). [In Russian]. Methods of calculating losses in transformers used for resistance welding are discussed.—S. K.

Assembly for the Gas Pressure Welding of Tubes. Iu. Ya. Shafit. (*Avtog. Delo*, 1948, No. 8, 19–22). [In Russian]. Details are given of an experimental assembly for gas pressure-welding of tubes; it consists of three main parts: (1) Specially equipped tractor; (2) hydraulic pressure-welding head with a multiple flame torch; and (3) pressure-gas reducing system.

Comparative Quality Characteristics of the Gas Pressure-Welded and Arc-Welded Tubes. S. M. Skorodzievskii. (*Avtog. Delo*, 1948, No. 8, 22). [In Russian]. The characteristics of welds obtained by these methods are compared.

Static Strength of Multiple-Spot Joints. A. S. Gel'man and I. A. Bakh. (*Avtog. Delo*, 1948, No. 8, 6–11). [In Russian]. An investigation of the effects on the strength of a spot weld of the number and relative positions of other welds in its vicinity using low-carbon steel plates 2, 4, and 6 mm. thick is reported.—S. K.

The Weldability and Mechanical Properties of a Series of Low-Alloy Steels. J. G. Ball and C. L. M. Cottrell. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 321–336). An investigation of the weldability and mechanical properties of a series of 27 experimental low-alloy Mn–Ni–Cr–Mo steels of constant carbon and molybdenum contents is reported; four nickel-free (< 0·1%) steels and four containing copper were also tested. All the steels were made in small H.F. induction-furnace melts, the weldabilities in the normalized condition being determined by a modification of the Reeve fillet-weld cracking test. The electrodes used had a rutile base coating. Diagrams indicating the effect of steel composition on weldability were compared with others indicating the mechanical strength of the steels in both the normalized and tempered condition; this led to a range of compositions giving the best combination of weldability and mechanical strength. The microstructure of the steels in the normalized condition is related to their weldability and the effect of tempering temperature after normalizing on the mechanical properties and microstructure of one of the steels is studied; evidence to support a significant relationship observed was obtained from some of the other steels of the series.

Hot-Cracking of Austenitic Welds with Special Reference to 18/13/1 Cr–Ni–Nb Alloy. E. C. Rollason and M. C. T. Bystram. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 347–352). A study was made of the influence of grain size, strain, and heterogeneity (both coring and non-metallic forms), intermetallic compounds, and the presence of ferrite and trace elements on the hot-cracking of austenitic Ni–Cr alloys. Hot bend and hot tensile tests have indicated that microcracks in the austenitic alloys occur at temperatures above 1250° C. Contributory factors are internal stress, heterogeneity of structure, and high sulphur content. The addition of 1–1½% of niobium, together with more than 0·09% of carbon has a beneficial effect when silicon is low (0·2–0·4%). Higher silicon contents are detrimental. To explain microcracking a hypothesis is suggested based on the fit of alloying elements in the transition lattice of the boundary; the beneficial effect of the presence of ferrite is also explained.

Static and Fatigue Tests on Spot-Welded Trusses. A. S. Joukoff. (*Rev. Soudure*, 1950, No. 3, 136–143: *Weld. J.*, 1951, **30**, May, 264s–265s). Light sections were spot-welded and subjected to static tests. Behaviour under static loads was satisfactory but fatigue properties were not.—U. E.

Calculation and Control of the Resistance of Spot Welds to Static Shear. H. Zschokke and R. Montandon. (*Rev. Soudure*, 1951, **7**, No. 2, 98–116). The value at which failure occurs in spot welds submitted to static shear depends on the diameter and shape of the spot weld and the geometrical dimensions of the test piece; the authors suggest a technique for examining the strength of spot welds which is independent of these variables. Detailed studies are made of stresses developed in test pieces, the effects of temperature on materials and the types of failure. Equations of failure are suggested covering transverse and longitudinal failure in the plate, failure near the spot weld, and pulling apart of the weld. (15 references).—M. D. J. B.

Pressure Vessel Design Effects of Pressurizing. R. E. Cecil. (Compressed Gas Assoc.: *Welding. J.*, 1951, **30**, May, 424–434) Low-pressure thin-walled vessels of steels A.S.T.M. A70, and A285 were investigated at twice the permissible service pressure. The heads, and areas around openings, attachments, and seams were deformed. This deformation may be considered as a stress-relieving operation. The 'jacket test' proved to be best for testing and evaluating high-pressure containers having rigid heads and bottoms which do not plastically deform at test pressure.—U. E.

Fusion Welded Pressure Vessels for Use in the Chemical and Allied Industries—(Discussion on the Provisional British Standard Code 1500 : 1949). (*Trans. Inst. Chem. Eng.*, 1950, **28**, 116–129).

The Weldability of Strip Electrodes Submerged in Powder. F. Erdmann-Jesnitzer and H. Neese (*Technik*, 1951, **6**, July, 325–329). The authors report progress in the development of a new automatic welding method, due to Neese, in which the electrode consists of a strip equal in length to the seam to be made, clamped in position above the joint. Straight butt welds up to 500 mm. long have been successfully reproduced. For best results the strip should not be less than 5 mm. thick, 100 mm. wide and the gap should be 2–3 mm. A.C. is more satisfactory; the arc potential should be 35–40 V., the current, for strips 5–8 mm. thick, is 1100–1300 amp. Protection is given by heaping powder on to the joint, so that the strip is partly submerged. The powder consists of 95% glass and 5% aluminium grit 1 to 3 mm. in size. So far, the method is inferior to the Elin-Hafergut process.—J. G. W.

Ellira Welding and the Influence of Hot-Working on the Tendency to Age. E. Uhlir. (*Schweisstechn.*, 1951, **5**, June, 64–68). The influence of hot working on the tendency of the weld deposit to age is dicussed. Additions of nickel and aluminium had no influence. An improvement was obtained with heat-treatment; hot working resulted in an increase in resistance to change on ageing.—U. E.

Electric Fusion Submerged-Arc Process Welds Expanded Steel Transmission Pipe. J. H. Middleton. (*Steel*, 1951, **128**, Apr., 23, 80–94). Expanded steel pipe with outside diameters of 20 to 30 in. and ¼ to ½ in. thick is being produced at the Gulfsteel Division of Republic Steel Corp. A description

is given of the preparation and formation of the flat plate into cylinders. The welding is performed by using twin arcs, about ½ in. apart, one using A.C. and the other D.C. Speed of welding is about 4 ft./min.—A. M. F.

Welding of Boilers in the U.S.A. J. Miroir. (*Mét. Constr. Méchan.*, 1951, **83**, June, 453, 457, 459, 461). This report on boiler welding techniques in the U.S.A. surveys blowpipe, and manual arc welding, and semi-automatic and automatic methods applied to sheets and plates, and argon arc welding of stainless steel and non-ferrous metals.—R. S.

Welded Spheres Solve Liquid Nitrogen Storage. J. A. Toland. (*Iron Age*, 1951, **167**, Mar. 29, 86–88). The construction of a 200-gal. sphere suitable for 5500 lb./sq. in. service at — 320° F. is described.—A. M. F.

The Formation of Spots in Welds. W. Eilender, H. Arend, and W. Neuhaus. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 261–263). The formation of bright spots, similar to flakes, found on the fracture surfaces of welds was studied. They represent the enveloping surfaces of gas bubbles and slag inclusions, but the moisture content of the electrode sheath and of the air does not appear to be responsible for hydrogen enrichment of the welds. Cleanliness and good welding conditions reduce spot formation; heat-treatment eliminates this. Spots entail a reduction in the strain-to-fracture; the tensile strength is not materially affected. Ageing the electrodes results in higher tensile strength of welds. Spots and pores have the same origin.—P. F.

Welding Fractures. E. P. DeGarmo. (*Metal Progress*, 1951, **60**, Aug., 74–77). The causes of fractures are considered as being improper design, poor-quality steel, and poor welding practice. The author is critical of the value of the conventional Charpy test, and prefers the Kinzel bend test.

E. T. L.

The X-Ray Test of Welds and the Quantitative Evaluation of Defects. O. Masi. (*Met. Ital.*, 1951, **43**, July, 216–269). The author's method is to determine the resistant thickness in welded traction test bars. The tests were carried out by photometric measurements after calibrating a film with a $D = f(S)$ diagram obtained by measuring the photographic densities D for the different thicknesses S of a calibrated sample. Three different cases are considered corresponding to the defects insufficient penetration, porosity, and inclusions.—M. D. J. B.

Resistance to Fatigue of Welded Connections. W. Soete and R. van Crombrugge. (*Rev. Soudure*, 1950, **6**, No. 2, 72–82; No. 4, 199–212; 1951, **7**, No. 2, 90–97). This paper describes research into the fatigue strength of welded joints carried out under the auspices of the "Commission des Assemblages Soudés de l'Institut Belge de la Soudure." The object is to provide a method of calculating welded connections for engineers and to supplement work done by Professor Roš. The behaviour of butt and lap joints under dynamic loading is investigated and work is carried out to assess whether the strength of weld metal under impact loading is a function of weld-metal thickness as in the case of static loading. The investigation covers freely welded butt joints, braced butt joints, **T**-joints connected by fillet welds, and lastly, lap joints. Comprehensive information is given on welding and testing procedure. Experimental results are discussed in detail.—M. D. J. B.

Repairing of Hardened Steel Gears by Oxy-Acetylene Welding. A. H. Barltrop. (*New Zealand Eng.*, 1950, **5**, Nov. 15, 1029). Recommendations on the welding of chromium steel gears are made.—R. A. R.

Arc Welding of Stainless Steel. M. N. Vuchnich. (*Canad. Metals*, 1951, **14**, May, 34–35, 38, 41–42). The arc welding of stainless steel construction is described and special welding techniques are recommended for the various ferritic and austenitic steels.—E. C.

Physical and Welding Metallurgy of Chromium Stainless Steels. H. Thielsch. (*Weld. J.*, 1951, **30**, May, 209s–250s). This is a review of published and unpublished information on the welding of martensitic and ferritic stainless steels. (213 references).—U. E.

Measuring the Tungsten Consumption in Inert Gas Arc Welding. G. Urbain. (*Weld. J.*, 1951, **30**, May, 260s–264s). Radioactive tracers were used in measuring tungsten losses in plate, weld metal, and fumes in inert gas arc welding. Tungsten consumption, while welding, was found to be about 50 mg./cm. for stainless steel, and half of this for aluminium and alloys.—U. E.

Oxy-Acetylene in Steel Fabrication. C. I. Orr. (*Canad. Metals*, 1951, **14**, Apr., 43–44). A survey is made of the wide range of applications of oxy-acetylene processes in steel fabrication.—E. C.

Welding in the Shipyard: Value and Application. E. D. Lacy. (*Iron Steel*, 1951, **24**, Sept., 423–425). The advantages of welding in ship construction are discussed.—G. F.

Cast Weld Construction. J. O. Felt. (*Weld. J.*, 1951, **30**, May, 415–423). Examples of components constructed by combining welded members with castings are described and illustrated.—R. A. R.

Steel Castings and Welding Can Be Combined Successfully. P. O'Keefe. (*Mat. Methods*, 1951, **34**, July, 73–75). There is an increasing tendency to use parts fabricated by welding together several steel castings or a combination of cast and wrought pieces. The author illustrates this with photographs of several such built-up structures, Types of casting most suitable for welding are described.—P. M. C.

Gas Welding of Cast Iron. T. Brownlie. (*New Zealand Eng.*, 1950, **5**, Nov. 15, 1027–1028). Recommendations on the welding of cast iron are made.—R. A. R.

Gray Iron Welding, Joining, Cutting. C. O. Burgess. (*Amer. Foundryman*, 1950, **18**, Oct., 50–57; Nov. 44–48; Dec., 48–53). This series of papers comprises chapter 7 of *Gray Iron Handbook*. by the Gray Iron Founders' Society, It covers applications of gas and electric welding and cutting.

Powder Cutting. L. Wolff. (*Schweissen u. Schneiden*, 1951, **3**, Aug., 256–260). The powder-cutting process (using iron powder) as developed in the U.S.A. is described.—U. E.

Powder Washing Process Ready. (*Steel*, 1951, **128**, June 25, 114). An oxy-acetylene method, developed by Linde Air Products Co., for the removal of sand incrustations, fins, pads, chill nails, and other excess metal from castings is described. The process, called powder washing, utilizes a special blowpipe equipped with an external powder-washing attachment. The castings are left smooth, clean, and to close tolerance.

MACHINING AND MACHINABILITY

The Effect of Speed and Feed on the Mechanics of Metal Cutting. B. T. Chao and G. H. Bisacre. (*Inst. Mech. Eng.* Mar. 31, 1951 *Advance Copy*). Tests were conducted on mild steel and copper over a wide range of speed, feed, and tool angle. The results showed: (1) Local heat in the chip has an important effect on the friction at the chip/tool interface; (2) for many purposes the effects of speed and feed can be treated as functions of the product of speed and feed; (3) temperature does not directly affect the shear strength of the metal; and (4) the extent of built-up edge prevailing can be put as a function of the product of speed and feed.—R. A. R.

An Instrument for Automatically Recording Waviness of Surfaces. C. W. Medhurst. (*J. Sci. Instruments*, 1951, **28**, July, 211–214). An instrument which automatically records the waviness of surfaces is described. Accurate and rapid traces can be made.—H. D. W.

On the Formation of Metal Turnings. G. Carro-Cao. (*Met. Ital.*, 1951, **43**, July, 270–280). After a brief review of the phenomena involved in the formation of short and long turnings, the author develops a theory explaining these phenomena based on embrittlement factors in the plastic deformation of metals.—M. D. J. B.

New Construction of Tangential Cutters. S. A. Rubinshtein. (*Stanki i Instrument*, 1948, No. 7, 14–16). [In Russian]. The theory of machining by tangential cutting is considered, and some improved cutter shapes are proposed.—S. K.

The Shape of Hard-Alloy Cutters for Multiple-Tool Machines. I. M. Neklepaev. (*Stanki i Instrument*, 1948, No. 7, 13–14). [In Russian]. A new shape for cutting tools is proposed.

S. K.

Cutting Conditions for the High-Speed Milling of Steels. P. P. Grudov and S. I. Velkov. (*Stanki i Instrument*, 1948, No. 7, 7–12). [In Russian]. Methods of selecting the optimum cutting conditions in the milling of many types of steel are proposed.—S. K.

Effect of Chip Breakers on Cutting Force in Broaching. F. P. Malikov. (*Stanki i Instrument*, 1949, No. 2, 17–18). [In Russian].

Special Features of Profile-Machining Operations. N. Ya. Niberg. (*Stanki i Instrument*, 1949, No. 2, 15–17). [In Russian]. The machining of convex and concave profiles is considered in relation to the movement of the milling cutter.

Internal Resonance—One of the Reasons for Vibration in Machining. L. B. Erlikh. (*Stanki i Instrument*, 1949, No. 1, 20–22). [In Russian]. The causes of and prevention of internal resonance in several cases of vibration during machining are considered.—S. K.

Investigation of the Optimum Shape of Milling Cutters for the Rapid Milling of Zh 1 and Zh 2 Stainless Steels. G. Z. Matskin and P. N. Pobegalov. (*Stanki i Instrument*, 1949, No. 1, 18–22). [In Russian].

The Tool-Making Industry in the Third Year of the Post-War Five Year Plan. N. S. Degtyarenko. (*Stanki i Instrument*, 1949, No. 1, 6–9). [In Russian]. The achievements of the machine-tool and tool-making industry of the U.S.S.R. are outlined.—S. K.

Machining a Steel by Grinding. N. I. Volskii. (*Stanki i Instrument*, 1948, No. 7, 20–23). [In Russian]. Experiments on the grinding of 15 types of steel with corundum discs are reported. It was found that: (1) Increasing the carbon contents of pearlitic steels leads to better grinding; (2) addition of chromium and nickel to low-alloy structural steel lowers productivity by increased toughness; (3) absence of oxidation of grindings in the case of austenitic steel lowers the productivity; and (4) structures can be arranged in the following order of increasing grinding efficiency: Austenite, martensite, troostite, sorbite and pearlite.—S. K.

Effect of the Nature of the Grain and Disc Bond During the Machining of Metals by Grinding. N. I. Volskii. (*Stanki i Instrument*, 1949, No. 2, 18–20). [In Russian]. Experiments are described on the grinding of tempered and normalized specimens of steels and cast iron. The performances of the corundum and carborundum wheels are compared, and the nature of disc wear and of its influence on grinding are discussed.—S. K.

Grinder Cutting of Steel and Non-Ferrous Metals. H. Winkelmann. (*Metall*, 1951, **5**, Aug., 336–337). Particulars are given of machines, grinding discs, and cutting times for cutting various metals.—J. G. W.

Manipulation of Corrosion and Heat-Resisting Steels. J. A. McWilliam. (*Welding Metal Fab.*, 1951, **19**, Apr., 133–139). Continuation of a paper (*see J. Iron Steel Inst.*, 1951, **169**, Sept., 74). Thermal conductivity values are tabulated of low carbon (up to 0·35%) and stainless steels. Heat-treatment methods, finishing operations, grinding, and polishing of martensitic and austenitic steels are discussed.

New Machining Techniques Make Available Benefits of New Alloys. L. B. Manlove. (*Western Metals*, 1951, **9**, Aug., 31–33). The author recommends slow speeds, fast feeds, and negative angles on carbide cutting tools when dealing with tough work-hardening alloys. Rolled threads are also discussed.—P. M. C.

CLEANING AND PICKLING

Descaling Ferrous Metals. G. Rossi-Landi. (*Mét. Constr. Méchan*, 1951, **83**, July, 544–555). The author discusses the concentration and temperature of baths in relation to the period of immersion. The part played by the 'attacking' acid and the 'residual' acid is explained. Notes are added on the preparation of acid baths, and acid consumption figures for rolled steel rods, sheets, strip, and tubes are given.—R. S.

The Action of Inhibitors in Acid Pickling of Steel, Part 3. M. Smialowski and Z. Ostrowski. (*Prace Badawcze Glownego Inst. Met.*, 1951, **3**, No. 3, 251–254). [In Polish]. The investigation of the rate of evolution of hydrogen in the reaction between HCl and iron or nickel in the presence of dibenzylsulphoxide (0·05 g./l.) at 40° C. showed that this inhibitor acts strongly (slowed down by 95%) on the reaction with iron only in the range from 1 to 3 *N* HCl, and on the reaction with nickel (slowed down by more than 70%) in the range from 4 to 12 *N* HCl. Iron and nickel plates connected together and immersed in HCl at 40° C. showed a reciprocal inhibition which diminishes with increasing acid concentration. Dibenzyl sulphoxide (0·05 g./l.) causes a decrease in the rate of hydrogen evolution on iron and nickel electrodes and a drop in current intensity of the cell Ni/HCl/Fe. Inhibition efficiency is only restricted to the concentration range 2 to 6 *N* HCl.—V. G.

High Speed Rod Bakers Expedite Production at J. and L. Wire Mill. (*Indust. Heating*, 1951, **18**, Apr., 679–684). This article describes the processing of rod coils in a straight-line cleaning system consisting of pickling, rinse, and lime tanks, and four pit-type, rod baking ovens.—J. A. L.

Automatic Transmission Castings Cleaned Chemically. R. J. Peters. (*Iron Age*, 1951, **167**, Mar. 15, 105–107). An automatic-cycle self-contained unit cleans transmission castings at the Warner Gear Div., Borg-Warner Corp. This unit dissolves all sand in pockets of the castings and inclusions on the surface. The process consists of a bath containing Kolene No. 4, a catalysed molten salt containing sodium hydroxide as the basic solvent, held at 825° to 900° F. Following this are cold- and hot-water rinse baths.—A. M. F.

Pickle Liquor Disposal Can Pay Off. F. D. Jones. (*Iron Age*, 1951, **167**, Mar. 8, 88–91). Numerous ways in which waste pickle liquors and galvanizing residues can be treated are reviewed. Sulphuric acid waste liquor can be treated with ground phosphate rock to remove the iron and sulphuric acid and give a superphoshate fertilizer.—A. M. F.

PROTECTIVE COATINGS

Leveling Solutions. A. Bregman. (*Metal Progress*, 1951, **60**, July, 56–60). This survey deals with practical details of plating metals to give a smoother surface. Reverse period plating, cobalt-nickel solutions, electrolytic and chemical polishing; and surface measuring instruments are considered.

Plating Wastes Treatment and Disposal. J. E. Cooper. (*Plating*, 1951, **38**, Apr., 346–352, 357). Cyanide and chromium waste disposal methods are reviewed and illustrated by flow sheets and data relating to the Willow Run and Ford-Monroe plants. Alkaline chlorination is recommended for cyanide waste, and reduction and precipitation with lime for chromium waste treatment.—A. G.

Activation of Metal Surfaces Preparatory to Being Electroplated. N. B. Balashova, Yu. S. Tsareva, and A. T. Vagramyan. (*Doklady Akad. Nauk S.S.S.R.*, 1950, **71**, No. 1, 73–75). Experiments to study the activating action of potassium cyanide and ethyl alcohol on copper and silver electrodes are described. Activation of the electrode surface in KCN solution occurs in a few seconds. Passivation in $AgNO_3$ solution occurs slowly (10 min.). Ethyl alcohol does not activate silver electrodes but it has a marked effect, similar to that of KCN, on copper electrodes.—R. A. R.

Metallic Surface Coatings for Gray Iron. C. O. Burgess. (*Product Eng.*, 1950, **21**, Dec., 108–113). The possibilities and methods of application of metallic coatings to gray iron are outlined. The properties developed and examples of the uses of each method are given.—A. M. F.

Metallic and Nonmetallic Coatings for Gray Iron. (*Foundry*, 1950, **78**, Dec., 76–79, 194–203). Metallic and non-metallic coatings successfully applied to grey iron to meet the requirements of appearance, and corrosion or wear resistance are discussed. Metal spraying and tinning by hot dipping, assisted by the successful use of chloride and nitrate fluxes, galvanizing, lead and lead–tin coatings, and aluminizing are also dealt with.—E. J. D. S.

Fatigue Loss and Gain by Electroplating. J. O. Almen. (*Product Eng.*, 1951, **22**, June, 109–116). The author stresses the dangers of salvaging worn parts by plating and shows how the fatigue strength of steels is greatly reduced when plated with metals such as copper, nickel, and chromium. A process is described whereby the advantages of rebuilding by electroplating can be retained without loss of fatigue strength. Developments in electroplating processes are suggested, by which electrodeposited coatings may be made as effective as shot peening in increasing fatigue strength of plated machine parts. The results of numerous fatigue tests and laboratory experiments are given.—M. D. J. B.

Exchange Mechanism between Chromium Ions in Solution and Metallic Surfaces. M. T. Simnad. (*Rev. Mét.* 1951, **48**, July, 522–524). Since a base metal may be deposited on a more noble one the phenomenon is not an electrochemical one. A preliminary investigation using radioactive chromium in solution and 18/8 steel, iron, chromium, and platinum is described. The steels were subjected to various passifying treatments, passivity in chromate solutions being due to the conversion of chromate at anodic points into a mixture of ferric and chromic compounds sealing up discontinuities. A. G.

Cementation with Chromium. F. Barbas. (*Usine Nouvelle*, 1951, **7**, Aug. 30, 23–27; Sept. 6, 29–30; Sept. 13, 29–30). Chromium forms a single-phase layer and in the passive state behaves electrochemically like the noble metals. The problems of metallic diffusion and the effect of contact

and temperature are discussed. The two methods of chromizing are described: (*a*) The powder method using ferrochromium mixed with kaolin, ammonium fluoride, and pieces of chromium, and (*b*) the gaseous method utilizing chromium fluoride vapour. The important characteristics of the layer are considered. Chromizing gives a hard corrosion-resistant layer taking a good polish, and permits the use of a cheap and easily machined base metal.—A. G.

The Universal Cold Chrome Process. T. J. Hollinrake. (*Australasian Plating Fin.*, 1951, **1**, Apr., 5–7). The advantages of the Universal Cold Chrome Process, used on an industrial scale by a Melbourne firm, are listed. With steels an intermediate deposit, usually zinc, must be employed. No nickel anodes or salts are used, and all baths are operated cold. Plant requirements are briefly indicated.—T. E. D.

Practical Methods in Heavy Industrial Nickel Plating. E. J. Roehl. (*Australasian Plating Fin.*, 1951, **1**, Feb., 9–13). The hardness of nickel deposits can range from 63 to 450 Vickers, as opposed to that of chromium, which lies between 400 and 950 Vickers. The tensile strength and ductility are greater than those of chromium. The preparation of the basis metal before plating is briefly described, and compositions of three plating baths are given. H_2O_2 or wetting agents may be used as anti-pitting agents. Nickel deposits can be machine finished; chromium can only be ground.—T. E. D.

The Electrolytic Process of the Manufacture of Tinplate. C. Frenkel. (*Proc. S. Wales Inst. Eng.*, 1951, **66**, Mar., 167–177). The Ferrostan electrolytic tinplate plant at Ebbw Vale and the improvements to be introduced at Trostre are described. Acid (stannous sulphate) electrolyte was chosen in preference to alkaline (stannate solutions) because it deposits twice as much tin for a given current, and current density can be considerably greater (400 amp./sq. ft.); this permits greater output without using a large tinning bath. Electrolytic alkaline degreasing and acid pickling were both found to be essential. Flow melting, by heating nearly to the melting point and then quenching, improves both adhesion and finish, and dilute chromic acid gives a thin film of protective oxide. The speed of the Ebbw Vale line was limited by the flying shear to 600 ft. per min., but improvements in this unit will allow the Trostre plant to run at 800 ft./min.—H. R. M.

Electrodeposited Tin–Nickel Alloy Coatings. N. Parkinson, S. C. Britton and R. M. Angles. (*Sheet Metal Ind.*, 1951, **28**, Aug., 757–767, 770). The authors summarize papers presented to the Electrodepositors' Technical Society. A hard deposit, of pleasing appearance, and containing 65% Sn, and 35% Ni can be easily and consistently obtained from solutions containing stannous and nickel chlorides, and sodium and ammonium fluorides. Details of these solutions, operating conditions, and equipment are outlined, and the results of corrosion tests are presented.—P. M. C.

Spray-Gun Bonderizing. (*Sheet Metal Ind.*, 1951, **28**, Aug. 768). A description is given of a new Bonderizing development by the Pyrene Co. Ltd., Brentford. A cold-processing solution is applied to sheet metal by means of an ordinary spray gun. The coatings produced are claimed to be as good as those produced by orthodox processes.—P. M. C.

Flat Polish and Phosphate Coated Steels Reduce Costs. (*Australasian Plating Fin.*, 1951, **1**, Apr., 17–19). Flat polishing of steel is more economical than polishing after forming, and the application of a suitable phosphate coating followed by a lubricant will prevent the formation of scratches and other imperfections during pressing.—T. E. D.

Phosphate Coatings. (*Australasian Plating Fin.*, 1951, **1**, Apr., pp. 9–13). Phosphate coatings are resistant to the commonest types of corrosion, and also overcome the poor paint-adhesive properties of smooth metal surfaces. There are two main methods of phosphatizing, Parkerizing and Bonderizing.—T. E. D.

Phosphate Coatings as a Basis for Painting Steel. Phosphate Coatings Panel of British Standards Institution. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 10–15). [This issue].

Tentative Analytical Tests for Phosphate Coatings on Steel. R. St. J. Preston, R. H. Settle, J. B. L. Worthington. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 19–20). [This issue].

Metal Surfacing for Original Parts. (*Product Eng.*, 1951, **22**, July, 122–124). The scope and advantages which may be derived from metal surfacing are briefly discussed. Very thin coatings by the high-vacuum process have recently opened new fields in metal surfacing. Resistance to abrasive wear and impact, and hot hardness are examined for a variety of base metals and surfacing alloys.—M. D. J. B.

Progress in Enamelling Techniques with Particular Reference to the Foundry Industry. H. J. Karmaus. (Brit. Cast Iron Res. Assoc.: *Giesserei*, 1951, **28**, Aug. 23, 397–401). Considerable progress in recent years has been made with the design and cleaning of castings for satisfactory enamelling. Improvements are also recorded in all stages of the enamelling process. The deleterious effect of a high sulphur content in the moulding sand has been realized.—J. G. W.

Porcelain Enamel Coatings. (*Product Eng.*, 1951, **22**, June, 141–148). This article deals with recent developments in porcelain enamel coatings. A new type allows a one-coat application directly on steel. The methods of application, types of enamel, and properties (abrasion resistance, thickness, chemical and corrosion resistance, weathering, thermal resistance, and impact resistance), are considered in detail.

Processing of "Land Rover" Components. (*Sheet Metal Ind.*, 1951, **28**, Aug., 769, 770). A description is given of the use of infra-red equipment for rapid drying and stoving. The surface pre-treatment and paint finishing of "Land Rover" components is carried out by a continuous process employing an overhead conveyor.—P. M. C.

The Measurement of Interlaminar Resistance of Varnish-Insulated Silicon-Steel Sheet for Large Electrical Machines. E. D. Taylor. (*Proc. Elect. Eng.*, Part II, 1951, **98**, June, 377–385). In large electrical machines it is essential to insulate the core laminations to reduce eddy-current losses. Varnishing the stampings before assembly in the core is one method. For developing varnishing technique measurement of the electrical resistance of the film of varnish is essential. The problem of this measurement is analysed and found to be a statistical one. A solution is suggested.—R. A. R.

Studies on Anti-Fouling Compositions. Part VII—The Leaching Rate During the Middle and Late Stages of Compositions Based on Cuprous Oxide as the Toxic Component. H. Barnes. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 360–367). Factors affecting the leaching rate of compositions containing cuprous oxide during the middle and late stages of immersion are considered. The results are based on leaching-rate studies made on a wide variety of composition formulated to elucidate these factors. Of major importance are the cuprous oxide content and the matrix formulation. The latter, with a given cuprous oxide content, determines the leaching rate. With many of the compositions investigated, the leaching rates dropped below their 'steady' value in the very late stages of soaking. This appears to be caused largely by the building up of a skeletal matrix residue. Methods are suggested whereby formulation can be adjusted to avoid this disadvantage.

POWDER METALLURGY

Flexible Design and Lower Costs Achieved by Powder Metallurgy. C. L. Bigelow. (*Western Metals*, 1951, **9**, Aug., 39–41). The precision, economy, and flexibility of the powdered-metal processes are discussed and illustrated by two examples.—P. M. C.

Role of Gases in the Production of High Density Powder Compacts. D. Warren and J. F. Libsch. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 774–781; *J. Met.*, 1951, Sept.). The influence of pressing and sintering conditions on the permeability and density of Fe–Co powder compacts and the effect of evolved gases on the sintering process are examined. Gases greatly influence the final density, and high sintering pressures and temperatures and rapid heating exaggerate this influence and cause large initial pores to form. A new method of determining the percentage of total pores connected to the surface in the compact is introduced.—G. F.

Production of Metal Powders by Atomization. W. Rutkowski. (*Prace Badawcze Glownego Inst. Met.*, 1951, **3**, No. 3, 259–266). [In Polish]. The historical development of the production of metal powders by granulation and atomization, and their economic importance are outlined.—V. G.

The "Flywheel" Effect in Infiltrated Metal Powder Parts. G. Stern. (*Metal Powder Assoc., Proc. Seventh Annual Meeting*, Apr. 25–26, 1951, 14–18). It is difficult to achieve uniform density in every section of pressed, sintered, and coined iron parts: however, when copper infiltration is effected, the density and physical properties of the final iron–copper part can be substantially equalized throughout. The effects

of iron compact density and percentage copper infiltration on final density, hardness, and strength are given. This technique is valuable for complicated parts hitherto considered unsuitable for powder metallurgy; it is used for making jet-engine compressor blades.—K. E. J.

Iron Powder Materials in High Frequency Transformers for Military Equipment. H. W. Lord. (*Metal Powder Assoc., Proc. Seventh Annual Meeting*, Apr. 25–26, 1951, 22–28). For the production of small military communication receivers, pressed iron powder cores provide a means for obtaining substantial reductions in the size of intermediate-frequency transformers. Where very high efficiency is desired in small units, ferrite core materials (produced from powdered metal oxides) are superior to the best pressed iron cores.—K. E. J.

Metal Powders in Some Small Arms Ammunition Applications. G. A. Miller, jun. (*Metal Powder Assoc., Proc. Seventh Annual Meeting*, Apr., 25–26 1951, 30–38). The possibilities and uses of powder-metallurgy techniques in the manufacture of the following ammunition parts are discussed: Bullets of 0·300-in. calibre, 20-mm. high-explosive and incendiary shell bodies and noses, fuze magazines, practice and armour-piercing 20-mm. shells, and 20-mm. cartridge cases. The technique promises rapid production, and may lead to new designs of ammunition.—K. E. J.

Sintered Iron Powder Rotating Bands for Ordnance Use. A. M. Burghardt. (*Metal Powder Assoc., Proc. Seventh Annual Meeting*, Apr. 25–26, 1951, 41–45): *Indust. Heating*, 1951, **18**, Aug., 1376–1378). Experimental developments are showing that high-quality sintered iron driving bands, made from commercially available iron powders, can give satisfactory results on high-velocity shells, and 90-mm. projectiles. Future applications to bands for smaller projectiles are probable.—K. E. J.

Powder Metallurgy *vs.* Drawn Wire Method of Producing Gears. J. Rigby. (*Metal Powder Assoc., Proc. Seventh Annual Meeting*, Apr. 25–26, 1951, 59–66). Powder-metallurgy methods are gradually being introduced for production of pinions, mainly from iron. Experience with this method and that of production from cold-drawn shaped wire shows that both eliminate machining processes, reduce material waste, and can be used for long runs. The advantages of the powder-metallurgy method are outlined.—K. E. J.

Metal Powder Applications in the Home Appliance Field. J. D. Carey. (*Metal Powder Assoc.: Proc. Seventh Annual Meeting*, Apr. 25–26, 1951, 68–77). Metal-powder parts are being used for such applications as gear trains in washing machines, racks and pinions for wringers, spur gears and links for fans, pinions for food mixers, and for bearings. Methods of manufacture and quality control of properties are described.

Shell Rotating Bands Successfully Made from Iron Powders. H. R. Clauser. (*Mat. Methods*, 1951, **33**, Apr., 61–65). Large-scale adoption of sintered iron powder rotating bands for projectiles is now a definite possibility, and in addition to the large saving in copper, iron bands appear to give better performance, particularly on high-velocity projectiles. German practice and recent work in the U.S.A. are described. Band sizes, iron-powder characteristics, and sintering and pressing procedures are dealt with.—P. M. C.

PROPERTIES AND TESTS

The Tensile Forces in Tightened Bolts. A. H. Stang. (*Product Eng.*, 1951, **22**, Feb., 118–120). The problems of tightening bolts and measuring the tension are discussed. Lubrication and the surface conditions of threads may give a wide variation in tension for a given torque. Nevertheless, satisfactory torque/tension relationships can be established when variables are carefully controlled.—M. D. J. B.

Compression Test Extensometer for Cylindrical Specimens. A. M. Stott and J. M. McCaughey. (*Product Eng.*, 1951, **22**, Apr., 157–160). This article describes an instrument for obtaining accurate stress/strain data when testing cylindrical specimens in compression. This accurate and easily calibrated extensometer, developed by the Pitman-Dunn Laboratory at Frankford Arsenal, can be used for ferrous and non-ferrous materials at temperatures ranging from — 70° to 400° F. Suitable recording equipment is available.—M. D. J. B.

Scatter in Transition Test Curves. Adrienne F. Scotchbrook, B. G. Johnston, and R. D. Stout. (*Weld. J.*, 1951, **30**, May, 266s–271s). Problems connected with the Lehigh slow notched-bend best are discussed. Many tests were made to study the transition curve at temperature intervals smaller than usual. Scatter was greatest in the transition range. It can be caused by variations in material within a plate, errors in measurement, and differences in the preparation of specimens.—U. E.

Some Quantitative Data Bearing on the Scabbing of Metals under Explosive Attack. J. S. Rinehart. (*J. Appl. Phys.*, 1951, 22, May, 555–560). Fracturing, or scabbing, of a material near a free surface caused by a transient compressional stress wave of high intensity impinging on that surface has been investigated using 0·20% carbon steel, a Cr–Mo steel, brass, copper, and an aluminium alloy and an explosive charge to produce the stress wave in the metal. Scabbing was governed principally by the spatial distribution of pressure within the wave and a critical normal fracture stress σ_c characteristic of the material and perhaps the state of stress. Numerical values of σ_c were obtained for each metal.

Investigation into the Premature Failure of Welt Needles. H. H. Symonds. (*J. B'ham. Met. Soc.*, 1950, **30**, Sept., 97–107). *See J. Iron Steel Inst.*, 1951, **168**, July, 326.

Strain Hardening—Effects of Alloying Elements and Microstructure. G. V. Smith. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 2–30). This review deals with the Meyer index, the Bauschinger effect, and the effects on hardness of temperature, strain rate, grain size, and alloying elements. Other sections include the solid-solution strengthening of steels. (26 references).—E. T. L.

Macro-Residual Stresses in Metals Resulting from Plastic Deformation. W. M. Baldwin, jun. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 31–56). This paper is a review of theoretical approaches to strip rolling, drawing, tube sinking, and tube drawing, with a consideration of the experimental data on the stress distributions.—E. T. L.

The Crystallographic Mechanisms of Translation, Twinning, and Banding. C. S. Barrett. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 65–98). Slip, faulting, stacking, disorder, twinning in different types of lattice, kink bands, and deformation heterogeneity are discussed. There are clear diagrams and photographs and 22 references.—E. T. L.

Deformation Textures. R. M. Brick. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 99–112). The author discusses the preferred orientation of grains that arises from deformation. Factors mentioned are temperature, previous structure, and the presence of solute atoms.—E. T. L.

Recrystallization Textures. C. G. Dunn. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 113–120). This review, with 32 references, covers the cubic texture of copper and nickel-iron, and grain growth of silicon iron.—E. T. L.

Dislocation Theory. W. Shockley. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 131–147). The author emphasizes the unsatisfactoriness of the theory, which should however be taken seriously. He justifies this by a simple explanation of the theory.—E. T. L.

Nucleation of Deformation. J. H. Hollomon. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 148–162). A qualitative thermodynamic explanation of the nucleation of phase-change leads to a discussion of the nucleation of slip, using Andrade's idea that strain-hardening results from the elimination of variations of stress concentration.—E. T. L.

The Effect of Strain Histories on the Work Hardening of Metals. T. E. Tietz and J. E. Dorn. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 163–179). Data on the effect of the temperature of straining on strain hardening, and on the effects of pre-straining and strain rate are presented and examined.—E. T. L.

Dynamics of Slip Bands. C. Zener. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 180–196). An expression is derived theoretically for the rate of stress relaxation; it agrees qualitatively with experiment. The author discusses slip, internal friction, creep, and plastic after-effects.—E. T. L.

Plastic After-Effects. J. G. Leschen. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 197–209). This general discussion deals with elastic and plastic after-effects, and the multiplication of slip bands.—E. T. L.

Work Hardening Under Combined Stresses. L. R. Jackson. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 210–222). Evidence is presented showing that, while the shape of the work-hardening curve is predictable from consideration of shear-strain energy, the termination of the curve depends on the hydrostatic stresses present during straining.—E. T. L.

The Creep of Metals. J. D. Lubahn. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 223–247). The author reviews the factors that affect the rate of deformation, including strain rate, slip, and the strain/time curve.—E. T. L.

Cold and Work Fatigue. A. M. Freudenthal. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 248–261). The inter-relation between cold work and fatigue is considered in three parts; namely, the effect of (*a*) cold work on the fatigue process; (*b*) fatigue in producing cold work; and (*c*) cold-working the specimen surface on the fatigue performance.

The Effect of Plastic Deformation on Solid Reactions, Part I—Diffusion Reactions. B. L. Averbach. (*Amer. Soc. Metals, Cold Working of Metals*, 262–289). Topics dealt with include precipitation hardening, the supersaturated solid solution, the influence of cold work on precipitation hardening, and recrystallization. Cold work accelerates ageing, and may reduce hardness after coherent precipitation, by destroying the coherency.—E. T. L.

The Fracture Stress of Metals as Affected by Plastic Deformation, the Stress System, and Size. D. J. McAdam, jun. (*Amer. Soc. Metals, Cold Working of Metals*, 1949, 321–364). This paper is in two parts, the size effect being discussed in the second. A conclusion in the first part, where emphasis is on microfracture, is that the fracture stress is determined by the critical value of either the shear stress or the octahedral shearing stress. The stress required for brittle fracture decreases with larger specimens.—E. T. L.

Experimental Research on "Wetting Effect" and "Liquo-Striction." C. Benedicks and R. Härden. (*Met. Ital.*, 1951, **43**, Sept., 383–397). The authors discuss how the strength of solids is affected by wetting with different liquids. The effect of wetting is a function of the surface tension of the liquid. The tendency of a solid to decrease in strength is inversely proportional to the hardness of the solid. A theoretical explanation of the phenomenon is offered. By 'liquo-striction' is meant the expansion of a solid when wetted by a liquid. Liquostriction is shown to increase with increasing surface tension of the liquid.

Plastic Deformation of Chromium-Plated Steel. (*Steel*, 1951, **128**, June 18, 108–114). The National Bureau of Standards recently studied the mechanical properties of chromium-plated SAE 4130 steel. The ability of plated specimens to undergo plastic deformation is substantially increased by baking at temperatures between 100 and 440° C. Moreover, baking at temperatures of 200 to 400° C. increases the load necessary to produce failure about 1·4 times and increases the deformation to about 55% of that of the unplated steel.

Macroscopic Surface Stresses Produced by Plastic Deformation. G. B. Greenough. (*J. Iron Steel Inst.*, 1951, **169**, Nov., 235–241). It is not possible to explain the residual lattice strains observed in plastically extended polycrystalline aggregates, using X-ray diffraction methods, entirely in terms of Heyn intergranular stresses. This paper is concerned with the possibility that macroscopic (large-scale) stresses are also present, superposed on the Heyn stresses, in iron and mild-steel specimens. It is shown that there is a macroscopic compressive biaxial stress in the surface of the aggregate; the layer containing this stress is, in the specimens used, about two crystals (8×10^{-3} in.) deep. The whole of the transverse component of this stress system is confined to the surface layer and is determined; the longitudinal component may not be entirely confined to the surface layer, and only the difference between its value at the surface and in the interior is measured.

Softening of Metals during Cold-Working. N. H. Polakowski. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 337–346). Steels and non-ferrous metals initially overstrained by tension, torsion, or drawing were progressively compressed in a direction opposite to that of the initial flow. In each case not only was a Bauschinger effect observed, but also an initial gradual decrease of the indentation hardness (by amounts up to 10%), before it increased. Both effects were reproducible and were more pronounced in the higher-carbon steels. A theory relating indentation hardness and the energy stored in a cold-worked metal is put forward as a tentative explanation of both the Bauschinger effect and work-softening. To satisfy this theory quenched and tempered steels should soften during the early stages of cold-working, and they are shown experimentally to do so. This energy concept accounts for the low rate of work-hardening during cold-working and fatigue testing of heat-treated, *i.e.*, sorbitic and troostitic steels. The softening effect provides an explanation of the recrystallization and mechanical properties of single- and polycrystalline metals after reversed deformation.

Photo-Elastic Stress Analysis in Relation to Production Engineering. S. Widdas. (*J. Inst. Prod. Eng.*, 1951, **30**, Jan., 12–28). The history and elementary theory of photo-elastic stress analysis are outlined. The avoidance of over-stressing during engineering design by application of this technique is illustrated by examples.—J. B. B.

Photoelastic Stress Analysis Useful in Design of Metal Parts. M. M. Leven. (*Mat. Methods*, 1951, **33**, Mar., 70–73; Apr., 89–92). Part I is devoted to the two-dimensional method of photoelastic stress analysis. The author outlines the construction of a large field, diffusion-type polariscope, and describes some of its applications. The photoelastic properties of Catalin C-61-893, Kriston. Columbia Resin CR39, celluloid, and annealed Marblette are tabulated. The 'frozen stress' technique, which can be applied to three-dimensional problems is described in Part II.—P. M. C.

Effects of Light Peening on the Yielding of Steel. H. L. Harrison and B. D. Mills, jun. (*Weld. J.*, 1951, **30**, May, 251s–253s). An investigation on plastic deformation of mild-steel strips axially loaded below the yield point and subjected to transverse hammering is reported. With a steady stress below 50% of the yield point a few hundred light blows of a flat-faced hammer caused appreciable plastic deformation which was confined almost entirely to the zone struck. Differences in room temperature and frequency of blows showed considerable effect.—U. E.

Multi-Channel Measurement of Physical Effects by Confluent Pulse Technique, with Particular Reference to the Analysis of Strain. J. G. Yates, D. H. Lucas, and D. L. Johnston. (*Proc. Inst. Elect. Eng.*, Part II, 1951, **98**, Apr., 109–121). Measurement of impedance bridges by pulse excitation is discussed. An application is described in which indications from ten resistance strain gauges are displayed on a single cathode-ray tube. Frequencies of 0 to 3000 cycles/sec. are resolved, and a max. sensitivity of 1 mm. on the screen corresponds to 0·001% strain. The performance of the pulse excitation method is considered.—R. A. R.

Electrical Strain Gauges and the Practical Application Thereof. N. G. Neuweiler. (*Microtecnic*, 1951, **5**, Mar.–Apr., 71–85). The fundamental theory of stress analysis is given together with details of the elastic properties of materials. In simple terms the derivation of Poisson's ratio is explained and used to calculate three-dimensional strain. The effect of design of the resistance strain gauge on its operation is discussed and a table of typical strain gauge details is included. The measurement of static and dynamic strain with special bridge circuit networks is described.—H. D. W.

Resistance Strain Gauges. T. B. Sansom. (*Elect. Rev.*, 1951, **148**, Jan. 5, 3–7). The application of A.C. bridge methods to the resistance-gauge method of measuring strains is described.—R. A. R.

An Examination of Fatigue-Testing Machines by Means of Strain Gauges. K. Fink and M. Hempel. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 265–273). A study of the correlation of the load-indicator readings, and the loads measured with strain gauges attached directly to specimens, was carried out on several fatigue-testing machines. Discrepancies much in excess of the permitted error of ± 3% were found. The dependence of the discrepancies on the type of machine, method of testing, temperature, and frequency was investigated. Fatigue-testing machine load-indicators should occasionally be recalibrated.—P. F.

Electrically Excited Resonant-Type Fatigue Testing Equipment. T. J. Dolan. (*Amer. Soc. Test. Mat. Bull.*, 1951, July, 60–67). A new fatigue-testing machine controlled by simple electrical circuits is described. The loads are applied by inertia forces from two heavy masses between which is suspended the test specimen. The system operates as a 'tuning fork' which subjects the specimen to vibratory bending stresses. The amplitude can readily be controlled. Preliminary results are presented from bending fatigue tests of round and of square specimens of 24S-T4 aluminium alloy to show the effect of shape of cross-section on the fatigue strength.—J. B. B.

Stress Raisers in Fatigue. R. C. A. Thurston. (*Canad. Min. Met. Bull.*, 1951, **44**, May, 347–355). Stress-concentration factors are discussed and methods of avoiding the effects of stress raisers or notches are examined. These

include shot peening, cold rolling, cyaniding, carburizing, and nitriding. The effects of these on notch fatigue strength of steels are given. Surface finish, corrosion, and metallic surface coatings are discussed. (18 references).—T. E. D.

Fatigue Durability of Prestressed Screw Threads. J. O. Almen. (*Product Eng.*, 1951, **22**, Apr., 153–156). After a brief discussion on fatigue failures in bolts the author describes the advantages of rolled threads which he claims are superior to cut and ground threads. Prestressing and stretching to reduce fatigue vulnerability of cut and ground threads are considered together with the more controllable method of superficial rolling.—M. D. J. B.

Determination of the Probability of Rupture during Creep under Multi-Directional Stress after Preliminary Cold Working. W. Siegfried. (*Rev. Mét.*, 1951, **48**, June, 413–433). Tapered threaded pieces of two austenitic steels were tested to rupture across the threads at high temperatures after various preliminary working treatments. After working, planes of greatest tension or grain boundaries may lead to the formation of discontinuities during creep. Under multi-dimensional stress only one-third as great a maximum stress is permissible as for simple tension.—A. G.

Fatigue Weakness of Surfaces. J. O. Almen. (*Product Eng.*, 1950, **21**, Nov., 117–140). The shortcomings of testing procedures, in that they only apply to limited types of loading, are pointed out and the effects of manufacturing processes on surface structure are discussed to give a more complete understanding of the problems associated with the strength of materials. The effects of residual stresses induced by shot peening, thermal treatment, and case hardening are examined in detail.—A. M. F.

Some Recent Observations in Micro-Hardness Testing. E. B. Bergsman. (*Amer. Soc. Test. Mat. Bull.*, 1951, No. 176, Sept., 37–43). Factors responsible for lack of agreement of results in microhardness testing have been examined. A method of calibration of the measuring device using an optical grating is described. Load dependence of hardness number has been observed for three materials (hardened steel, soft annealed 18/8 stainless steel, and soft iron). Meyer's analysis of load dependence is erroneous. Calculations support the interpretation that load dependence arises from elastic recovery after unloading.—J. B. B.

885° F. Embrittlement of the Ferritic Chromium–Iron Alloys. J. J. Heger. (*Metal Progress*, 1951, **60**, Aug., 55–61). The embrittlement at 885° F. is accompanied by an increase of hardness, tensile strength, and yield strength; other measurements described show that there is a decrease in ductility and impact strength. It is suggested that the cause is the precipitation of sigma phase, or some transitory phase preceding its formation.—E. T. L.

Hardness Scale Selector for Steel. E. F. Bradley. (*Metal Progress*, 1951, **60**, Sept., 80, 80B). A table shows the correct type of hardness measurement that should be made with different thicknesses of material, and different hardness ranges. The right choice avoids the 'anvil effect.'—E. T. L.

Experimental Survey of Low-Load Hardness Testing Instruments. A. R. G. Brown and E. Ineson. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 376–388). A review of the literature is followed by a brief description of the available low-load hardness testers, and the method of operation used in this survey. The absolute low-load hardness values obtained vary considerably, because of the large number of uncontrolled variables. The need for a standard method for preparing and testing specimens and for reporting results is shown.

A Micro-Indentation Hardness Tester for Attachment to the Vickers Projection Microscope. S. J. Lloyd and D. J. Norris. (*J. Sci. Instruments*, 1951, **28**, Mar., 81–84). An instrument for attaching to the Vickers projection microscope for hardness testing with impression sizes of 5–10μ has been constructed. For very soft materials a load range below 1 g. was required. The instrument is accurate, provided the impression size is greater than 5μ; sensitive measurements of hardness can be made under loads of 0·5 g.—H. D. W.

An Automatic Light-Load Bergsman Type Hardness Tester. P. Grodzinski. (*J. Sci. Instruments*. 1951, **28**, Apr., 117–121). To overcome difficulties encountered with a Bergsman microhardness tester with loads up to 200 g. for testing corundum, sintered tungsten carbide, and silicon carbide a stronger model has been designed to work with loads up to 3000 g. It has a new type of diamond indenter consisting of the intersection face of two cone faces of the same axis but of opposite cone angle.—H. D. W.

A Microhardness Tester for Metals at Elevated Temperatures. A. Brenner. (*Plating*, 1951, **38**, Apr., 363–366). An apparatus for determining the hot-hardness of thin electrodeposits and microhardness of bulk metals at temperatures up to 900° C. is described. Six specimens, mounted on a sliding carriage inside a thermostatically controlled electric furnace filled with an inert gas, are tested in a single heating cycle. Load on the diamond indenter, mounted on a fused silica shaft, is varied from 30 to 200 g. by suitable adjustment of gas pressure inside the furnace, and above 200 g. by dead-weight loading. Results of hardness measurements are plotted for many electrodeposits.—A. G.

Molybdenum Corrects Temper Embrittlement from Phosphorus. J. J. Harwood. (*Steel*, 1951, **128**, Apr. 23, 78). The effects of phosphorus on the toughness of AISI-SAE 1340 and SAE 5140 steels have been studied. The transition temperature is raised and the susceptibility of the steel to temper embrittlement is increased. A good tolerance for phosphorus in tempered martensite can be obtained by replacing part of the manganese in 1340 by molybdenum or by replacing part of the chromium in 5140 by molybdenum with little change in hardenability.—A. M. F.

Metallic Transfer between Sliding Metals: an Autoradiographic Study. E. Rabinowicz and T. Tabor. (*Proc. Roy. Soc.*, 1951, **208**, Sept. 24, 455–475). Friction and metal transfer between sliding metal surfaces in the absence and in the presence of boundary lubricant films are studied. One surface is made radioactive and is slid over the second surface, the amount of metal transferred being detected by the blackening of a photographic plate placed in contact with this surface. A range of hard and soft metals is studied. The results indicate that friction between metals is due to the formation and shearing of metallic junctions. The main function of lubricants is to reduce metallic interaction.—T. E. D.

Internal Friction of Ferromagnetic Materials. A. Ferro and G. Montalenti. (*J. Appl. Phys.*, 1951, **22**, May, 565–568). The authors verify experimentally the hypothesis that, in cyclically stressed ferromagnetic materials, energy loss because of magneto-elastic internal friction is influenced by a domain motion due to the applied stress itself.

New Magnetic Particle Testing Technique Speeds Inspection of Ferrous Parts. S. G. Kelley, jun. (*Mat. Methods*, 1951, **33**, June, pp. 66–68). The author describes the new Duovec magnetic particle inspection technique, which is an improvement of the conventional magnaflux technique. The new method uses a moving magnetic field, which magnetizes the part under test in many directions. It thus makes possible the location of defects in any direction in one inspection operation. Details of the capabilities and limitations of the method are given, and its use in the high-speed routine examination of diesel-engine connecting rods is described and illustrated.—P. M. C.

Magnetic Particle Inspection. N. G. Neuweiler. (*Microtechnic*, 1951, **5**, May–June, 127–138; July–Aug., 165–170). Basic concepts of magnetism, and the creation of a suitable magnetic field within specimens are considered. Faults or discontinuities in the specimen disturb the magnetic flux, part of which then passes outside the specimen forming leakage fields which attract finely divided ferromagnetic particles. Methods of creating magnetic fields by D.C., A.C., and rectified A.C. are described with instances of the application of flash magnetization. Best results are obtained with dry ferromagnetic powders and half-wave A.C. rectification. The detection of sub-surface defects is dealt with.—H. D. W.

New 'Fisher' Identifier of Steels. F. Strasser. (*Tecn. Indust.*, 1951, **29**, July, 629–630). [In Spanish]. This is a brief note on the applications of the Fisher electronic identifier developed by Jones and Laughlin and the Fisher Scientific Co. of Pittsburgh.—R. S.

An Electronic Instrument for the Measurement of the Damping Capacity of Materials. A. D. N. Smith. (*J. Sci. Instruments*, 1951, **28**, Apr., 106–109). An instrument for measuring the damping capacities of materials at frequencies from 50 to 10,000 cyles/sec. is described. The time taken for the amplitude of vibration to fall to half its value during free decay is measured by an electronic circuit, which transmits two pulses to an electronic timing instrument.—H. D. W.

An Improved Direct-Reading X-Ray Microdensitometer. A. Taylor. (*J. Sci. Instruments*, 1951, **28**, July, 200–205). An improved microdensitometer for use with X-ray diffraction patterns is described. It is manually operated and employs the Dobson split-beam principle. Having replaced the gas-filled photocell and the Lindemann electrometer by a selenium photocell and galvanometer, a feed-back unit was necessary to obtain the speed of response and sensitivity required. A detailed account of the feed-back unit is given.—H. D. W.

Observations Concerning the Technique of Gamma-Ray Quality Control. H. Gerbeaux and M. Evrard. (*Métaux-Corrosion-Indust.*, 1951, Apr., 159–165). The equipment required for examination of welds by gamma rays and the safety precautious necessary, are described. Some photographs are reproduced and their interpretations discussed. With proper care, gamma rays can give as good results as X-rays, and the work can be reduced if the weak areas are first located with a Geiger counter.—N. McE.

Radiographic Techniques for Examining Steel Castings. (*J. Iron Steel Inst.*, 1951, **169**, Dec., 367–369). This report, by the Non-Destructive Testing Sub-Committee of the Steel Castings Division of the Brit. Iron Steel Res. Assoc., describes a series of radiographs of a set of steel plates varying from $\frac{7}{8}$ to 8 in. in thickness. Different radiographic techniques were used, including gamma rays of from 110–1000 kV. with lead and tungstate screens; their relative merits for each thickness are determined.

Manual on Quality Control of Materials. (*Amer. Soc. Test. Mat.*, 1951, Jan., *Spec. Tech. Publ.*, 15-C, 1–127). This book replaces a previous A.S.T.M. Manual on Presentation of Data. Part 1 covers the presentation of data in a concise form, and discusses the application of statistical methods and the condensing of information contained in a single set of n observations. In Part 2 the problem of presenting limits to indicate the uncertainty of the average of a unique sample of n observations is discussed. Such limits are known as 'confidence limits'; the meaning of these limits is explained, and constants for computing 99, 95, and 90% confidence limits are included. Part 3 presents formulæ, tables, and examples useful in applying the control-chart method of analysis of observational data obtained from several samples. This method provides a criterion for detecting lack of statistical control of quality.

Creep under Complex Stress Systems at Elevated Temperatures. A. E. Johnson. (*Inst. Mech. Eng.*, Nov. 15, 1951, Advance Copy). A general comparison is made of the complex stress-creep characteristics of a cast 0·17% C steel, a magnesium alloy, an aluminium alloy, and Nimonic 75. At low and moderate stresses the materials obeyed creep-rate/stress relations of the simple St. Venant and von Mises type. At high stresses pronounced anisotropy of a relatively complex type occurred in the first three materials at all temperatures used. Throughout the whole range of stress for all materials the creep obeyed quite closely the Hencky criterion of plastic flow.—R. A. R.

Gas Turbines—Some Metallurgical Considerations Involved in their Manufacture. H. Trivedi. (*Indian J. Phys.*, 1951, **25**, Jan., 35–52). This paper deals with metallurgical aspects of the gas turbine. The properties of materials now used are reviewed and a new material, titanium carbide, prepared by the author is discussed. Some aspects of gas-turbine research in America are reviewed.—J. A. L.

Fundamental Effects of Cold Working on the Creep Resistance of an Austenitic Alloy. D. N. Frey and J. W. Freeman. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 755–760; *J. Met.*, 1951, Sept.). The improvement in creep resistance of an austenitic alloy by cold-working was studied. Creep resistance and internal structure were correlated, using the X-ray diffraction technique, on a low-carbon alloy (0·13% C, 1·43% Mn, 0·34% Si, 20·73% Cr, 18·92% Ni, 19·65% Co, 3·05% Mo, 1·98% W, 0·98% Cb, 0·14% N, balance Fe). Cold-working improves the creep resistance due to elastic stresses left in the lattice after working, the optimum improvement at any given reduction being obtained with any temperature of reduction below that which allows relaxation of stress during working. Increasing cold reduction increases the creep resistance only to the point where internal stresses are so high that a significant amount of relaxation occurs at the temperature considered. This critical amount of cold work decreases as the service temperature increases.—G. F.

Thermal Variation of Young's Modulus in Some Fe–Ni–Mo Alloys. M. E. Fine and W. C. Ellis. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 761–764; *J. Met.*, 1951, Sept.). The effect of additions of up to 10% Mo to iron–nickel alloys containing about 40% Ni on the Young's modulus of the alloy and its temperature coefficient was studied. The addition diminished the sensitivity of the thermal coefficient to composition changes, and modified the modulus through its effect on ferromagnetism and interatomic binding energy. The temperature range of nearly constant Young's modulus was greatly extended by work hardening.—G. F.

Russians Have New Heat-Resistant Alloys. S. L. Case. (*Iron Age*, 1951, **167**, Mar. 22, 65–69). This article is an extended abstract of Russian research publications in the field of iron–chromium–aluminium alloys published by the U.S.S.R. Academy of Sciences. Shortages of nickel and cobalt stimulated the development of these alloys as a substitute for nickel–chromium in electrical resistors. The mechanical and electrical properties at various temperatures, sealing characteristics, and hot- as well as cold working- properties are considered. The electrical resistance of such ternary alloys increases with increased aluminium and chromium, the former exerting a stronger influence.—A. M. F.

The Use of Mild Steel for Service at Sub-Zero Temperatures. F. H. Keating and E. V. Mathias. (*Proc. Inst. Mech. Eng.*, 1950, **163**, W.E.P. No. 55, 27–40). An investigation to determine the limiting sub-zero temperature at which mild steel may safely be used, in relation to notch brittleness, is described. Small welded vessels were tested to destruction at −80° C. Although such vessels fail in a brittle manner, actual rupture is preceded by a considerable amount of plastic flow. In general, provided recommended precautions as to quality of material and care in fabrication are taken, mild-steel welded equipment may safely be used down to −50° C.

Effect of Hydrogen on the Properties of Low-Alloy Steels. J. D. Hobson and C. Sykes. (*J. Iron and Steel Inst.*, 1951, **169**, Nov., 221–227). A method is described by which hydrogen is introduced into steel specimens by heating them in the gas at high pressures. The deleterious effect of hydrogen on the ductility of a number of low-alloy steels has been investigated and shown to be reproducible, provided that their heat-treatment is also considered. Hydrogen additions have the same effect whether carried out by electrolysis or by the high-pressure technique.

Comparison on the Effects of Alloying Elements on the Lower and Upper Transition Temperatures in Pearlitic Steels. J. A. Rinebolt and W. J. Harris, jun. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 20). A lower transition temperature for the change from plastic to brittle fracture in the Charpy test was established; this is less affected by carbon than the upper transition temperature, whereas nickel decreases the lower more rapidly than the upper transition temperature. Silicon up to 1·03% decreases the lower but increases the upper transition temperature.—E. T. L.

Boron Steels for Constructional Parts and for Carburizing. P. R. Wray. (*Metal Progress*, 1951, **60**, July, 52–55: *S.A.E. J.*, 1951, **59**, July, 46–52). **Boron Steels in the Present Emergency.** P. R. Wray. (*Steel*, 1951, **129**, July 2, 78–82). Steels containing boron instead of the rarer nickel, chromium, or molybdenum have been tested for their mechanical properties. Boron steels have improved machinability but need to be selected with care.—E. T. L.

Boron Steels. Metallurgical Advisory Board. (*Metal Progress*, 1951, **60**, Aug., 81–92). This is a summary of steelmaking practices, applications, and properties of boron steels which can be used as a reference for furthering their application with a view to conserving alloying elements in short supply.—R. A. R.

Caterpillar's Experience with Boron Steels. (*Metal Progress*, 1951, **60**, Sept., 66–68). Boron steels have presented no difficulties in machining, forging, or heat-treating, but the structure of the steel has to be adjusted to suit the operation.

"Preflex"—A New Type of Prestressed Beam. L. Baes and A. Lipski. (*Ossature Métallique*, 1951, **16**, Sept., 419–427). A detailed description of the design and production of a new beam of prestressed concrete containing a **T**-shaped steel core is given. Experimentally obtained data show this beam to be superior to similar beams of conventional design.—P. F.

Effects of Decomposition of Retained Austenite During Tempering on Notch Toughness and Tensile Properties. E. F. Bailey and W. J. Harris, jun. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 19). Quenching a low-alloy steel so as to give less than 40% retained austenite results in an acicular structure whose decomposition products have good notch toughness.—E. T. L.

Effect of Retained Austenite upon Mechanical Properties. L. S. Castleman, B. L. Averbach, and M. Cohen. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 21). Experiments show that retained austenite reduces the elastic limit, yield strength, fracture stress and energy absorption in tension, and the slow-bend notch toughness.—E. T. L.

Designers Look to Stronger Airframe Materials. L. Schapiro. (*Steel*, 1951, **128**, Apr. 16, 77–80). Three steels with a tensile strength of 230,000 lb./sq. in. are now being produced for the aircraft industry. The ductility, impact resistance, and hardenability compare favourably with the SAE 4340 steel previously used. Notch effects are no greater for these new steels. The possibilities of titanium alloys and precipitation hardening stainless steels are discussed.—A. M. F.

Meehanite Castings Find Wide Use in Steel Plants. C. E. Herington. (*Steel*, 1951, **128**, Apr. 9, 81–82). A table, giving the physical properties of general engineering and heat-resisting types of Meehanite castings, is accompanied by illustrations of items made of Meehanite.—A. M. F.

Acicular Cast Iron in Textile Machinery. (*Nickel Bull.*, 1950, **23**, May, 78–80). The picking mechanism which propels the shuttle of a loom from side to side is subjected to very severe fatigue stresses. This mechanism and the Ni–Mo acicular cast iron used for certain parts of it are described.

METALLOGRAPHY

Examination of Structure in the Third Dimension. H. Klemm. (*Metall*, 1951, **5**, Aug., 337–341). Three-dimensional metallography is described. Examples are given of micro-stereographic photographs and of explorations in depth by successive repolishing and re-etching. The calculation of volumetric grain size is also explained.—J. G. W.

Phase-Contrast Metallography. E. C. W. Perryman and Mary Lack. (*Metallurgia*, 1951, **44**, Aug., 97–102). The phase-contrast microscope is described and its metallurgical application discussed. Examples are given showing the sensitivity of the microscope in revealing small differences in surface level. Reference is made to its use as an aid in solving research problems and in the interpretation of electron micrographs.—J. B. B.

A Simple Reflecting Microscope for High-Temperature Metallography. D. W. Dewhirst and M. J. Olney. (*J. Iron Steel Inst.*, 1951, **169**, Nov., 209–220). Various types of microscope objective of unconventional design, and of possible value to the metallurgist, are described. Special reference is made to systems capable of giving high magnification but with large working distance, suitable for high-temperature metallography. A detailed description of the design, construction, and adjustment of a simple reflecting microscope with a bi-spherical monocentric objective of 0·5 N.A. and 17 mm. working distance is given, with information on photographic techniques. A complete apparatus for the examination of specimens *in vacuo* at temperatures up to 1000° C., and some typical results obtained by its use, are described.

High Temperature Microscopy with a Reflecting Objective. G. C. Smith and M. J. Olney. (*Research*, 1951, **4**, Sept., 437–438). A furnace designed for high-temperature microscopy, and a bi-spherical reflecting microscope objective of 0·5 numerical aperture have been used to observe, and record photographically, the formation of graphite on the surface of hypereutectoid steel cooled *in vacuo* from the austenite range. Details of its construction and application are given.

The Electron Microscope and Its Applications. M. E. Haine, R. Tostevin, R. S. Page, and R. G. Garfitt. (*Metro Vick Gaz.*, 1950, **23**, July–Aug., 216–223; Sept.–Oct., 242–248). The theory and construction of the EM3 electron microscope are explained and described with examples of its applications.—R. A. R.

Preparation of Replicas for Electron Metallography. W. J. Craig. (*Metal Progress*, 1951, **60**, Aug., 68–71). Practical details are given for making parlodion replicas.—E. T. L.

An X-Ray Diffraction Laue Microcamera. W. H. Barnes and S. Wagner. (*Canad. J. Techn.*, 1951, **29**, July, 337–342). A microcamera for obtaining symmetrical transmission and back-reflection Laue photographs of single crystals of micro-dimensions is described, with a drawing. The camera design is similar to that of the Chesley-Philips microcamera, with the important addition of a back-reflection film holder, a goniometer assembly, and improved transverse controls for the specimen. The camera has been used for the identification of unknown single microcrystals of the tetragonal and hexagonal systems.—T. E. D.

Accuracy of Measurement in X-Ray Studies of Microstructure. F. Gunther. (*Technik*, 1951, **6**, June, 281–282). Conclusion of a paper (*see J. Iron Steel Inst.*, 1951, **169**, Sept., 89). The author concludes that the radiation intensity in the Debye-Scherrer cone, and therefore the blackening of the photographic emulsion, is symmetrical only in the case of a uniformly fine-grained substance. He demonstrates that the accuracy with which the lattice constant may be determined, is limited by the nature of the diffraction process. In order to determine the lattice constant to 10^{-4} Å, the specimen must have a uniform grain size of about 1μ.—J. G. W.

Electrolytic Etching—The Sigma Phase Steels. J. J. Gilman. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 12). Details of the electrolytic etching solutions suitable for studying the sigma phase in stainless steels are given.—E. T. L.

Microscopical Examination of Iron Containing Manganous Inclusions. R. E. Lismer and F. B. Pickering. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 48–50). [This issue].

Production Problems—VII : Broken Motor Car King Pin. (*Iron Steel*, 1951, **24**, Aug., 371–372). A metallurgical examination of a broken motor-car king pin is described.

The Electrolytic Isolation of Carbides. P. Koch. (*Arch. Eisenhüttenw.*, 1951, **22**, May–June, 155–157). A procedure for isolating the carbides from a molybdenum steel is described. This is a modification of the Klinger-Koch method in which an alternating current of rectangular wave form is employed. The most suitable potential and other conditions for obtaining the carbides have been determined. It is stressed that the electrical conditions must be chosen and maintained for each particular type of steel if accurate and reproducible results are to be obtained.—J. P.

Chi Phase in Alloy Steels. K. W. Andrews and P. E. Brookes. (*Metal Treatment and Drop Forg.*, 1951, **18**, July, 301–311). The new 'chi phase' (χ), which is closely related to the 'sigma phase' (σ), has been identified by X-ray investigations in Cr–Ni–Mo steels of the 18–8–3 and 19–12–3½ types. Its occurrence depends on the presence of molybdenum, and its X-ray powder pattern is similar to that obtained from α-manganese. The nature and structure of chi and sigma phases are discussed; their occurrence can be approximately related to the equilibrium diagram for Fe–Cr–Ni with the aid of factors equivalent to replacing chromium by $Cr + 4(Mo + Nb) + 3Si - 12C$. A scheme for indicating the influence of molybdenum, silicon, and other elements on the formation of carbide, sigma, austenite, and ferrite, is put forward. (24 references).—P. M. C.

Kinetics of Precipitation in Supercooled Solid Solutions. G. Borelius. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, June, 477–484; *J. Met.* 1951, June). In this study of the kinetics of precipitation phenomena, the author first discusses the theory and then gives the results obtained by continuous resistometric and calorimetric measurements at the precipitation temperature, using alloys of the systems Au–Pt, Au–Ni, Pb–Sn, Al–Zn, and Al–Cu. The results of calorimetric investigations on the precipitation of nitrogen and carbon from solutions of α-iron are also given. In addition to the phase boundaries, the upper and lower limits of the ranges of existence of the various metastable states probably have a marked influence on the precipitation phenomenon, and these limits are sufficiently fundamental to form part of the phase diagram.—G. F.

Variations in Structure of the 2¼% Chromium 1% Molybdenum Heat-Resisting Steels. L. Habraken. (*Rev. Univ. Min.*, 1951, **7**, May, 164–180). The author studied structures in these steels using electron microscopic and radiocrystallographic techniques. Slight variations in chemical composition or in the rate of cooling rapidly lead to important structural modifications. He finds that the evolution of three different structures in the course of heating to 550° C., or during creep determination at the same temperature (under variable load), is very similar. An increase in the rate of structural modification occurs with high tension (19 kg.m./sq. mm.). There exist for steels, as for pure metals, two distinct creep processes.

Three complex carbides (Fe, Cr, Mo)C_6, Fe_4Mo_2C, and (Fe, Cr)$_3C$ are identified.—B. G. B.

Sigma Phase in Stainless—What, When, and Why. G. V. Smith. (*Iron Age*, 1950, **166**, Nov. 30, 63–68; Dec. 7, 127–132). This article reviews the known facts about the formation of sigma phase in iron–chromium and iron–chromium–nickel alloys and discusses its effect on embrittlement at high temperatures, and the increased corrosion rates that can occur.

The Sigma Phase in Alloys Containing Iron and Chromium. C. Vollers. (*Metalen*, 1951, **6**, June 15, 199–206; June 30, 223–227). [In English]. The author describes the nature of the sigma phase and of its formation in stainless and heat-resisting steels. The influence of alloying elements, temperature, and cold work on the formation of sigma are discussed in detail. The effect of sigma phase on the mechanical properties and corrosion resistance is examined and some methods of identifying this phase are indicated.—R. S.

The Formation of Sigma Phase in 13 to 16% Chromium Steels. H. S. Link and P. W. Marshall. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 11). After severe cold work sigma phase has been formed by ageing at 565° C. or 480° C. The sigma phase appears to harden the metal, suggesting that the so-called '885° F. embrittlement' is due to incipient sigma-phase precipitation.—E. T. L.

Composition Limits of Sigma Formation in Nickel–Chromium Steels at 1200° F. (650° C.). M. E. Nicholson, C. H. Samans, and F. J. Shortsleeve. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 13). X-ray diffraction experiments on a variety of steels have been carried out to improve the Fe–Ni–Cr iron–nickel–chromium ternary diagram.—E. T. L.

Grain Structure of Aluminium-Killed, Low Carbon Steel Sheets. R. L. Solter and C. W. Beattie. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 721–726; *J. Met.*, 1951, Sept.). The factors which promote the elongated grain structure in these sheets are: (1) A residual content of 0·015–0·066% Al; (2) heating the hot-rolled strip to above the coarsening temperature and cooling quickly; (3) cooling the hot-rolled strip near the lower critical temperature; (4) cold-reducing the hot-rolled strip more than 30% without preliminary reheating; and (5) annealing after cold-reduction using a slow heating rate or a heat-treatment at 700–1100° F. before the final anneal. An explanation of this behaviour is put forward.—G. F.

Preferred Grain Orientation in Steel Castings. J. D. Lavender and J. I. Morley. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 26–28). [This issue].

Principles of the Experimental Study of Pseudo-Symmetrical Crystal Lattices by Debye-Scherrer Photographs. R. Faivre. (*Soc. Française Mét.: Rev. Mét.*, 1951, **48**, June, 447–461). Interpretation is achieved by analysis of the deformation necessary to bring a fictitious lattice, possessing the limiting symmetry, into coincidence with the actual lattice. The principles of interpretation are discussed, the method being applicable to such substances as lead oxide, martensite, and certain other mineral solid solutions.—A. G.

Elastic Deformation of Single Crystals and Polycrystalline Masses. L. Guillet. (*Métaux-Corrosion-Ind.*, 1951, Apr., 153–158). The author begins by discussing the interatomic forces involved in elasticity, and the differences in Young's modulus along the different crystallographic axes due to anisotropy. He then considers polycrystalline systems, with particular reference to copper and its alloys.—N. McE.

Bragg Camera with a Heart-Shaped Cam for Oscillating the Crystal. J. M. Torroja and E. Pajares Diaz. (*Rev. Ciencia Apl.*, 1951, **3**, May–June, 208–215). [In Spanish]. The theoretical cam profile for a Bragg camera has been studied. The profile should follow a particular heart-shaped curve, but for usual working conditions an Archimidean spiral is quite adequate.

Magnetic Study of Fe–C–N Alloys. J. Pomey, R. Coudray, and J. Moulin. (*Rev. Mét.*, 1951, **48**, July, 552–560). In carburized steels near the eutectoid composition nitrogen between 0·5–1·25% (1) lowers the temperature of the A_1 transformation; (2) lowers the temperature of the beginning of the martensite transformation; (3) increases 1000 times the duration of incubation of the intermediate transformation to bainite (4) increases by 5 to 100, depending on temperature, the time to achieve the isothermal bainite transformation.

A. G.

Isothermal Transformation, Hardening and Tempering of 12% Chromium Steel. R. L. Rickett, W. F. White, C. S. Walton, and J. C. Butler. (*Amer. Soc. Metals*, 1951, Oct., *Preprint* 17). Eleven steels were studied, and great differences in austenitization rates were found, not all relatable to composition differences. Delta ferrite in austenite accelerates austenite decomposition, and decreases hardenability.

Investigations on the Isothermal Austenite Transformation by Undercooling. E. Greulich. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 245–260). In nine plain carbon steels of 0·18–1·4% C content and six alloy steels containing 0·09–0·73% C, 0·4–1·8% Mn, 0–0·85% Cr, 0–0·35% Mo, 0–0·34% Ni and 0–0·17% V the isothermal austenite transformation was determined by hardness measurements on specimens (20 × 15 × 2–3 mm.) which had been quenched from a temperature above the A_3 point to temperatures below the A_1 point in a sodium hydroxide melt, and kept there for varying periods before final water-quenching. Pearlite and martensite stages were present; an intermediate stage appears to be absent. The **S**-curves of all steels examined were of the exponential x^2 type in the pearlite stage, except for the complex alloy steels, where they were asymmetric. In the martensite stage, below 250–300° C. the austenite transforms slowly into martensite; below 160° C. the transformation was rapid. Between the pearlite and martensite transformations an incomplete pearlite transformation took place, the degree of completion depending upon the temperature. The intermediate stage is not regarded as distinct from the other two stages, but as a retarded pearlite transformation.—P. F.

Investigations of the Austenite Transformation of Structural Alloy Steels by Undercooling. H. Krainer and M. Kroneis. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 232–244). The **S**-curves of six steels containing Cr–V–Mo were constructed from experimental results obtained by two methods. In the first, thin steel discs were kept at different constant temperatures for given periods, and then water-quenched. From subsequent hardness measurements on these samples the **S**-curves were constructed. In the second method, a series of end-quench specimens was end-quenched over different periods and finally completely water-quenched. A qualitative correlation of results from both types of experiments is possible but it is difficult quantitatively. The pearlite transformation is characterized by the formation and growth of nuclei. Growth involves the diffusion of carbon in austenite and ceases almost completely below 400–600° C., when diffusion becomes difficult. The martensite transformation is induced in regions of low carbon concentration such as are assumed on statistical grounds to exist in the austenite lattice. If holding at a constant temperature does not lead to the disintegration of the martensite, the transformation depends only upon the temperature, not upon the length of the treatment. The intermediate stage in the transformation resembles the martensite transformation; the nuclei in this and the martensite stage are identical, and diffusion of carbon in α-iron participates in the process. The similarities in these two stages are reflected in the similarities of the end-products and their similar influence on the stability of the austenite.—P. F.

Isothermal Formation of Martensite at Subzero Temperatures in a High Chromium Steel. S. C. Das Gupta and B. S. Lement. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 727–731; *J. Met.*, 1951, Sept.). The isothermal formation of martensite in a 15% Cr, 0·7% C steel at sub-zero temperatures was studied. This formation occurs at temperatures below −65° C., being always preceded by athermal transformation; quenching in liquid nitrogen to −197° C. suppresses the isothermal, but not the athermal, transformation. The steel can be stabilized against isothermal transformation at a given sub-zero temperature by subjecting it to a cycle between that temperature and room temperature.—G. F.

Effects of Alloying Element on the Breakdown of Austenite at Sub-Zero Temperatures—Pt. I. J. O. Ward, M. D. Jepson, and J. R. Rait. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 1–10). [This issue].

Burst Phenomenon in the Martensitic Transformation. E. S. Mackhin and M. Cohen. (*Trans. Amer. Inst. Min. Met. Eng.*, 1951, **3**, 746–754; *J. Met.*, 1951, Sept.). The martensite reaction in single crystals and polycrystals of 70/30 Fe–Ni alloys is autocatalytic in nature, producing sudden bursts of transformation during cooling, the temperature of the first burst being below that at which martensite is first formed. Tests indicate that internal strains, either within the austenite or around existing martensite plates, control

the nucleation process in these alloys. The growth of the plates is not limited by the attainment of an elastic balance with the austenitic matrix, but by the occurrence of plastic deformation at the martensite boundaries, which interferes with the propagation mechanism.—G. F.

Constitution and Properties of Cobalt–Iron–Vanadium Alloys. D. L. Martin and A. H. Geisler. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 1). A portion of the Co–Fe–V phase diagram near the equiatomic FeCo composition was determined by thermal analyses and X-ray diffraction studies. Most of the alloys studied showed pronounced hardening after ageing between 400° and 700° C.—E. T. L.

Phase Relationships in the Iron-Chromium-Vanadium System. H. Martens and P. Duwez. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 2). Many alloys (120) were made from powder or by heating in a helium arc furnace, aged in vacuum at 700° C. for ten days and then used for determining the phase boundaries at 700° C., by X-ray diffraction. The sigma phase extends across the ternary diagram from the iron–chromium to the iron–vanadium side.—E. T. L.

Interstitial Diffusion. A. G. Guy. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 6). Existing data are used to show that diffusion phenomena are adequately described by an activity diffusion coefficient independent of solute concentration. Expressions are derived for three possible diffusion constants governing diffusion of carbon in austenite. The usual concentration diffusion constant has little fundamental significance. Data on the 'place exchange coefficient' should permit determination of the energy of activation of the elementary 'jump' process.—E. T. L.

Anisothermal Diffusion of Carbon in Austenite. J. E. Black and G. E. Doan. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 9). A mathematical treatment of results of carbon concentration at an interface at 980° C. in a non-uniformly heated bar shows that there are only small differences between the anisothermal and the classical isothermal carbon penetrations.—E. T. L.

Carbide Reactions in High Temperature Alloys. J. R. Lane and N. J. Grant. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 10). Carbides were separated out from a range of steels and analysed chemically and by X-ray diffraction. Most alloys contained either Cr_4C or Cr_7C_3; the latter became converted to the former on ageing. Nitrogen is present in the carbide lattice.—E. T. L.

Ferrite Formation Associated with Carbide Precipitation in 18Cr-8Ni Austenitic Stainless Steel. E. J. Dulis and G. V. Smith. (*Amer. Soc. Metals*, Oct., 1951, *Preprint* 14). Experiments with microscope, and high-temperature X-ray and magnetic measurements, show that the ferrite that forms in 18/8 steel after heating between 540° and 705° C., arises during cooling, rather than during the sensitizing.—E. T. L.

The Principles of Thermodynamics. P. W. Bridgman. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 1–15). This is a simple explanation of the concepts of energy and entropy.—E. T. L.

The Role of Statistical Mechanics in Physical Metallurgy. C. Zener. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals.*, 1950, 16–27). The author traces the derivation of the Boltzman relation between entropy and randomness, and considers its application to solid solubility, diffusion, and precipitation.—E. T. L.

Application of Thermodynamics to Heterogeneous Equilibria. L. S. Darken. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 28–46). This outline deals with the principles of continuity applied to thermodynamic functions, the interpretation of free-energy diagrams, and with some metastable phenomena.—E. T. L.

On Equations of State and the Phase Diagrams of Simple Binary Alloys. A. W. Lawson. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 85–101). A mathematical treatment leads to equations of state for dilute solid solutions. There follows a discussion of the entropy of mixing, and of the derivation of equilibrium diagrams from the equations of state.—E. T. L.

The Thermodynamics of Liquid Metallic Solutions. J. Chipman and J. F. Elliott. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 102–143). This review covers the experimental methods of deriving for liquid metals the free energy, entropy, and enthalpy. The author considers phase-diagram computations, computational methods in obtaining the entropy, ternary systems, and activity. (139 references).—E. T. L.

Phenomena Accompanying Precipitation from Solutions of C and N in Alpha-Iron. C. Wert. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 178–200). The author describes experiments on precipitation mainly using the technique of damping-capacity measurements. The data obtained show that carbon precipitates in spherical form, and nitrogen in plates. Age-hardening occurs during the precipitation, the latter usually taking place in two stages.

Eutectoid Decompositions. J. C. Fisher. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 201–241). The pearlite transformation in steel is first consdered in a theoretical approach which explains the pearlitic structure. A similar quantitative treatment is applied to martensite and bainite formation in terms of the growth of new phases and nucleation. (41 references).—E. T. L.

Thermodynamics of the Martensitic Transformation. M. Cohen, E. S. Machlin, and V. G. Paranjpe. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals* 1950, 242–270). The authors take as the model for the mechanism of martensite formation from austenite a two-stage process (face-centred-cubic structure becoming body-centred-cubic, and then body-centred-tetragonal), and elaborate on the thermodynamics of this. They compare theory with experiment, explaining the temperature dependence of the transformation. stabilization, conditioning, and isothermal formation of martensite. (29 references).—E. T. L.

A Nucleation Problem in Ferromagnetism. L. J. Dijkstra. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 271–281). The problem is to find how stable nuclei of reversed magnetization arise in a homogeneous matrix, and it is briefly considered.—E. T. L.

Contribution of Thermodynamics to Metallurgical Research and Operations. J. B. Austin. (*Thermodynamics in Physical Metallurgy : Amer. Soc. Metals*, 1950, 307–319). This is a brief review of the history of the theory of metal physics. (37 references).—E. T. L.

Determination of the Transformation Range by the Modified End-Quench Method. E. D. Bia. (*Faculty of Engineering, Montevideo, Inst. Ensayo de Materiales : Boletin de la Facultad de Ingenieria, No.* 23, 1950, **4**, Oct.). Some end-quench tests on 0·80–1·10% C steels and steels with 1·5% Cr, 2·5% W, and 0·25% V are described.—R. S.

Industrial Applications of the Isothermal Transformation of Austenite. M. Torrado. (*Tecn. Met.*, 1951, **7**, Mar., 58–66). [In Spanish]. Methods are outlined for determining **S**-curves and the morphology of the aggregates of the isothermal transformation of austenite. **S**-curves, determined by the Technical Research Establishment for the Spanish Iron and Steel Institute, are given and practical applications of isothermal treatments are described.—R. S.

Theoretical Metallurgy and Its Applications. J. M. Pertierra. (*Tecn. Met.*, 1951, **7**, Jan.–Feb., 1–18). [In Spanish]. The author surveys the part played by thermodynamics in the field of physical metallurgy.—R. S.

CORROSION

The Corrosion Situation: Past, Present and Future. U. R. Evans. (*Chem. and Ind.*, 1951, Aug. 25, 706–711). The author recommends that firms should appoint scientists to specialize in the problem of corrosion, the seriousness of which is commonly underestimated. He then outlines some of the advances made.—N. McE.

Corrosion Factors in Design. F. M. Reinhart. (*Product Eng.*, 1951, **22**, July, 101–107). The influence on corrosion of acidity, oxidation, temperature, agitation, impurities in the corrosive solution, surface conditions, stress, heat-treatment, joining dissimilar metals, and fabricating methods are discussed. Six types of corrosion, atmospheric, under-water, galvanic, concentration-cell corrosion, stress corrosion, and fretting are examined and methods of minimizing, controlling and, where possible, preventing corrosion are suggested.

Electrochemical Studies of Protective Coatings on Metals. Part III—The Correlation between Conductance or Capacitance and Area of Breakdown of Paint on Steel Immersed in Sea Water. F. Wormwell and D. M. Brasher. (*J. Iron Steel Inst.*, 1951, **169**, Nov., 228–234). The electrical conductance or capacitance of a pair of painted metal plates immersed in an electrolyte is not directly proportional to the area of paint

breakdown because of (1) the spreading in the electrolyte of the 'lines of conduction' between exposed areas, and (2) the effect of the thickness of the rust deposit. By observing certain precautions an approximate estimate of the area of breakdown can nevertheless be obtained and hence the method may prove useful when the area is too ill-defined to be measured visually. For the paints and conditions investigated, the rate of penetration of corrosion at exposed areas is independent of the relative areas of exposed metal and of intact paint film. This suggests that no appreciable cathodic action occurs on the areas of intact paint.

Interim Report of Service Trials of Steel Coal Wagons (1939–1950). J. C. Hudson. (*J. Iron Steel Inst.*, 1951, **169**, Nov. 250–256). Service trials have been in progress since 1939 on floor plates of four different compositions built into 100 steel coal wagons belonging to British Railways. Observations over the first ten years indicate that the life of the plates should be about 25 years in mild steel but that this life should be at least doubled by the use of copper-bearing steel or low-alloy steels of the copper–manganese or the copper–chromium type. The author concludes that the superstructure of coal and mineral wagons should be built of copper-bearing or low-alloy steels.

Electrolytic Probe for Underground Corrosion Studies. W. Beck. (*J. Met.*, 1951, **3**, Sept., 706–711). Experiments on the determination of the densities of corrosive currents on the surfaces of buried pipelines, using the electrolytic probe are described. The probe is a small insulated cylindrical segment of steel pipe placed on the outside surface of the pipeline, connected to it through a low-resistance current recorder. The results are sufficiently accurate for many practical purposes. The technique is also more flexible and less complicated, and results can be taken simultaneously at a number of points.—G. F.

Potential and Current Requirements for the Cathodic Protection of Steel in Soils. W. J. Schwerdtfeger and O. N. McDorman. (*J. Res. Nat. Bur. Stand.*, 1951, **47**, Aug., 104–112). Potentials of steel in 20 air-free soils varying in *p*H from 2·9 to 9·6 were determined in the laboratory. These data and the potential–*p*H relation for the hydrogen electrode were used in fixing the optimum potential for the cathodic protection of the steel against corrosion. The effectiveness of this potential of the cathodic protection of steel in soils was confirmed by weight-loss measurements on electrodes that were maintained at the selected potential in five corrosive soils. Cathodic polarization curves are interpreted in terms of the potential and current requirements for the cathodic protection of steel in soils.

Electrochemical Behaviour of Paint Films in Sea-Water. J. E. O. Mayne. (*Chem. and Ind.*, 1951, Apr. 14, 293–294). Measurements of the potential developed by painted steel specimens immersed in tap water or sea water showed that they always became more cathodic than bare steel. Crennel's interpretation of this is rejected, and an explanation, based on the high electrical resistance of the paint film, and not violating the principle of differential aeration, is advanced.

Electrochemical Examination of the Mild-Steel/Stainless-Steel Galvanic Couple. A. Indelli and L. Felloni. (*Chim. e Ind.*, 1951, **33**, June, 348–352). [In Italian]. In the mild-steel/stainless-steel couple the stainless is always the cathode whatever the conditions of acidity of the attacking agent. This remains true even if chromites and sulphuric acid are added to the medium. Coupling mild steel to stainless steel nearly always reduces the resistance to corrosion of one or the other metal and in some cases of both. For certain concentrations of acid and chromite the behaviour of the stainless steel changes from a passive (when isolated) to a completely active state when brought into contact with mild steel. The causes are discussed.—M. D. J. B.

The Five Properties Concerned in the Transport of the Active Corrodant Agent. R. C. L. Bosworth. (*J. Pro. Roy. Soc. N.S.W.*, 1950, **84**, Part I, 53–58). Corrosion of a metal by a corrodant liquid which attacks the surface uniformly is controlled by five physical properties: (*a*) The maximum rate, (*b*) the conductance, (*c*) a compliance term, (*d*) an inertia term, and (*e*) the electrochemical driving force. All five terms can now be determined. The compliance term is shown to be dependent on the solubility of oxygen in the corrodant.—T. E. D.

Statistical Study of Corrosion Resistance of 18/8 Steel in Acid Copper Sulphate Solution. J. Bleton, J. Blanot, and P. Bastien. (*Rev. Mét*, 1951, **48**, July, 525–536). A direct relation is found between the amount of corrosion and the percentage of carbon and chromium while nickel appears to have little effect. The formula $Cr - 80C > 16 \cdot 8$ indicates whether a cast is good or bad.—A. G.

Methods and Apparatus for Testing the Resistance of Metals to Stress Corrosion. E. Gasior. (*Prace Badawcze Glownego Inst. Met.*, 1951, **3**, No. 3, 241–250). [In Polish]. A critical review of methods of testing resistance to stress corrosion is given. Tests under constant load and under constant deformation are distinguished. Testing mild steel by Brenner's method is described.—V. G.

Corrosion by Retained Treatment Chemicals on Phosphated Steel Surfaces. S. G. Clarke and E. E. Longhurst. (*J. Iron Steel Inst.*, 1952, **170**, Jan., 15–18). [This issue].

The Nature and Scope of Temporary Corrosion Preventives. D. Clayton and M. C. Thompson. (*J. Inst. Petroleum*, 1950, **36**, July, 423–428). A description of some of the temporary corrosion preventives, such as soft-film and hard-film materials and oil types, together with some of the newer developments is given. The field of use is defined, and the principal causes of failure reviewed; the contribution of important accessory properties is mentioneds.—J. B. B.

Assessment of the Protective Value of Temporary Corrosion Preventives (with Particular Reference to Humidity Cabinet Tests). T. G. Clinton. (*J. Inst. Petroleum*, 1950, **36**, July, 428–435). The factors likely to produce breakdown of temporary corrosion preventives under service conditions are considered, and performance tests of such coatings are discussed. The use of a humidity cabinet and an intermittent salt-spray test is described in detail. Accelerated weathering, continuous salt-spray, and natural weathering tests are mentioned. There is no single test available to forecast the behaviour of protectives under all condition.—J. B. B.

Use of the Weatherometer and Humidity Cabinets for Evaluation of Temporary Corrosion Preventives. W. Pohl. (*J. Inst. Petroleum*, 1950, **36**, July, 436–448). A weatherometer, humidity cabinet, and outdoor exposure were all used to evaluate the efficacy of temporary corrosion preventives. While there is no precise relationship between the three types of test, the rough parallelism is useful in evaluating selected formulations.—J. B. B.

A Method for the Evaluation of Soft-Film Temporary Corrosion Preventives for Ferrous Articles. T. P. Hoar and G. C. Smith. (*J. Inst. Petroleum*, 1950, **36**, 448–457). A very thin but reproducible film of soft-film temporary corrosion preventive is deposited from a volatile solvent on to a clean steel surface, and the incidence of corrosion due to small drops of distilled water is determined after 24 hr. The technique has been used to evaluate the relative protective value of several compositions of mineral jelly with amphipathic substances. The composition of three parts of mineral jelly with one part of lanolin is considerably better than the plain jelly, and the substitution of wool grease for lanolin is even better. The addition of 2% of sodium petroleum sulphonate to the above compositions greatly improves their protective value. High-melting-point mineral jellies are somewhat more protective than plain mineral jelly, but petroleum sulphonate additions impair their performance. The results are discussed.—J. B. B.

Application of an Accelerated Atmospheric Corrosion Test to the Assessment of Temporary Corrosion Preventives. R. St. J. Preston and E. G. Stroud. (*J. Inst. Petroleum*, 1950, **36**, July, 457–463). An accelerated atmospheric corrosion test, in which specimens are exposed in a controlled humid atmosphere containing SO_2, has been applied in the assessment of temporary corrosion preventives. The protectives included materials ranging from light lubricating oils, through petroleum jelly, to bitumen. The average order of failure of steel panels coated with the protectives, exposed in various parts of the United Kingdom in unheated sheds, approximated to that obtained in the laboratory test of one week's duration.—J. B. B.

Tests of the Protective Value of Temporary Corrosion Preventives on Steel. S. G. Clarke and E. E. Longhurst. (*J. Inst. Petroleum*, 1950, **36**, July, 463–473). Free exposure to the outdoor atmosphere, the Armament Research Establishment salt-spray test, and a non-streaming humidity test

gave comparable orders of merit for several temporary corrosion preventives on steel. Outdoor exposure is generally too severe and variable for testing oil films. A sprayed-on water droplet test discriminated between oil films. Increasing protection with rising film weight was demonstrated with lanolin. A marked reduction in the weight of steel corroded in the A.R.E. salt-spray test was produced by extremely thin oil films.—J. B. B.

Temporary Corrosion Preventives for Aviation Uses and Methods of Testing Them. E. W. J. Mardles and J. Mason. (*J. Inst. Petroleum*, 1950, **36**, Aug., 475–487). Mention is made of the numerous temporary corrosion preventives—including corrosion-preventive lubricants—which have been used in connection with aviation. Special features of temporary protectives are discussed. Methods of test are treated in the order: Exposure, accelerated mechanical, special tests for engine corrosion inhibitors, other laboratory tests, and Norma-Hoffmann bomb oxidation tests. Results by the last-named method are presented and discussed; this method is important in developing temporary protectives.—J. B. B.

American Methods of Testing Temporary Corrosion Preventives. C. F. McCue and E. R. Blane. (*J. Inst. Petroleum*, 1950, **36**, Aug., 487–494). A critical review is presented of methods used in the U.S.A. both in the laboratory and in the field, for assessing the degree of protection afforded by temporary corrosion preventives. The significance of results obtained is discussed. The best assessment of performance can sometimes be obtained by considering the results of two or three different tests in conjunction.—J. B. B.

Performance Tests, Other Than Corrosion Tests, on Temporary Corrosion Preventives. H. Hollis. (*J. Inst. Petroleum*, 1950, **36**, Aug., 495–504). Brief details of the methods of test currently used in the performance testing of temporary corrosion preventives are discussed. Freedom from corrosive action, ease of removal, and good keeping qualities in the container are essential to all preventives. Specific tests of the following classes are given: (1) Oils; (2) soft, thin, non-drying films deposited from solvent solution; (3) hard, thin films deposited from solvent solution; (4) thick greasy films; and (5) strippable coatings, thick or thin.—J. B. B.

ANALYSIS

Modern Methods of Analysis. J. Pearson. (*Swansea Met. Soc.*, 1949, Nov. 12, 1–31). This pamphlet deals briefly with methods used in inorganic analysis, with particular reference to the more important developments and their applications. A survey of modern balances is followed by a summary of combustion and extraction methods and by an indication of the uses of organic reagents in analysis. Spectrophotometric methods are considered and turbidimetric methods and ultra-violet and infra-red photometry are mentioned. The uses of emission spectrography and flame photometry are indicated. Titration methods in modern use include those employing fluorescent indicators and electrometric titrations. Coulometry and polarography may be considered as electrodeposition methods; the latter is described in some detail. Paper chromatography is a method not yet fully worked out. Finally, examples are given of applications of these newer methods. (23 references).—T. E. D.

Statistics as a Tool of the Analyst. W. C. Thomas. (*Yearbook Coke Oven Man. Assoc.*, 1951, 222–236). The presentation and use of statistics are discussed in relation to the requirements of the coke-oven industry.—T. E. D.

Observations on the Inefficacy of a Desiccator in Determining the Moisture in Coal. R. Belcher and R. A. Mott. (*J. Appl. Chem.*, 1951, **1**, May, 204–209). An ordinary desiccator is of little use in preventing absorption of moisture by the dried coal regardless of the efficiency of the desiccant in it.—R. A. R.

The Potentiometric Determination of Carbon. W. Oelsen, H. Haase, and G. Graue. (*Arch. Eisenhüttenw.*, 1951, **22**, July–Aug., 225–229). CO_2 obtained by the combustion of the carbon-bearing substance, is precipitated as barium carbonate in a dilute baryta solution. The ion concentration in the solution is thereby diminished, and a potential drop is measured between the standard calomel and platinum electrodes submerged in it. The sensitivity is greatest in the vicinity of zero potential difference, and consequently the titration is carried out with a standard baryta solution so as to maintain the potential difference at approximately zero. It is possible to titrate electrolytically without adding baryta. The method is suitable for small samples and low carbon contents. In a multiple analysis about five minutes are required for the determination, including weighing. The experimental error is of the order $\pm$ 0·002% C.—P. F.

Chemical Determination of Magnesium in Cast Iron. W. Westwood and R. Presser. (*Analyst*, 1951, **76**, Apr., 191–199). The method is based on the dissolution in HCl, extraction of most of the iron with isopropyl ether, removal of manganese and some of the remaining elements by electrolysis with a sodium amalgam cathode, formation of complex ions with citric acid of any remaining interfering elements, and double precipitation of the magnesium as phosphate. Zirconium interferes.—J. B. B.

Determination of Boron in Metal Borides. H. Blumenthal. (*Anal. Chem.*, 1951, **23**, July 992–994). Boron is separated from the metals by precipitating them with barium carbonate after using a sodium carbonate fusion to bring the sample into solution. It has been successfully applied to the borides of iron, chromium, tungsten, titanium, zirconium, thorium, vanadium, niobium, tantalum, calcium, cerium, aluminium, boron carbide, boron nitride, and boron. The method is quicker than the methyl borate distillation.—J. B. B.

A Method for the Determination of Copper in Steels and Cast Irons. E. J. Lumley. (*Commonwealth of Australia, Dept. Supply, Aeronautical Res. Lab.*, 1951, June; Structures and Materials Note 188). Copper is precipitated as sulphide from a solution of the steel or cast iron in H_2SO_4, in which iron is present in the ferrous condition. The copper sulphide is ignited to oxide, converted to sulphate and copper estimated iodimetrically or electrolytically. The general procedure must be modified if the steel contains tungsten; molybdenum if present in appreciable amounts, must be separated from the copper during the analysis.—T. E. D.

Modified Photometric Determination of Copper in Ferrous Alloys. K. W. Nance. (*Anal. Chem.*, 1951, **23**, July, 1034–1035). The photometric determination of copper in ferrous alloys, according to the method of Dunleavy, Wiberley, and Harley, is modified to obviate the use of a *p*H meter.—J. B. B.

Determination of Hydrogen in Liquid Steel by Vacuum Extraction at 600° C. J. Bleton, S. Mischonsniky, G. Coin, and P. Bastien. (*Rev. Mét.*, 1951, **48**, June, 471–485). A review of other methods is given with an account of the mode of operation of the present method. Degassing a sample 12 mm. in dia. for about 1 hr. gives quick results with an accuracy of $\pm$ 0·5 c.c./100 g. For mild steels the hydrogen contents (c.c./100 g.) are: Acid open-hearth 3–6; acid electric 3·5–8; basic electric 4–10; and basic open-hearth 5–12. By suitable control of furnace operations and additions the hydrogen content may be halved.—A. G.

Radio-Autographic Determination of Lead in Stainless. L. R. Staditer and M. G. Fontana. (*Metal Progress*, 1951, **60**, July, 65–69). Experiments are described where radioactive lead in stainless steel was used to show on an autographed photograph the distribution of lead. It was concluded that in Durimet 20 alloy the lead does not segregate preferentially at the grain boundaries.—E. T. L.

The Determination of Oxygen by the Gotta Method. J. Massinon, N. Stoll, and M. Urbain. (*Rev. Univ. Min.*, 1951, **7**, Sept., 265–281). A systematic investigation of the Gotta method of oxygen determination was carried out in three different laboratories. The influence of the time of cementation at constant temperature and the influence of temperature on cementation were studied; the optimum temperature is 1300° C. The mechanism of the diffusion of aluminium was examined. Aluminium from different sources, having different analyses has no influence on the final oxygen determination. The segregation of oxygen across the section and the length of a billet were determined. The concentrations of nitrogen in the samples are also given. The agreement between the Gotta and the vacuum-fusion methods was satisfactory.—B. G. B.

The Photometric Determination of Molybdenum and Tungsten in High-Speed Steels. F. Jungblut. (*Chim. Anal.*, 1951, **33**, Aug., 248–251). In the colorimetric determination of molybdenum as the thiocyanate complex, tungsten and vanadium interfere, and extinction corrections must be applied. In addition, some molybdenum is thrown down with the tungstic acid precipitate in the determination of tungsten in steels, and must be determined separately. The methods are described.—T. E. D.

Characteristics of Fuels and Analyses of Gas. M. Moine,

K. P. Perry, M. Pigrais, and R. Poncet. (Comité International d'Études sur le Rayonnement de la Flamme; *Chaleur et Ind.*, 1951, **32**, Sept., 243–254). The properties of the tar–creosote and fuel oil used in the international trials at Ijmuiden are given. The gases coming from three points in the trial furnace, after combustion of the two fuels, were analysed using an Orsat apparatus. The results of 48 trials are tabulated as CO_2, O_2, and the excess of air represented by these figures. The construction and use of the Ostwald and the Pigrais diagrams and formulæ for representing combustions are presented and examined.—T. E. D.

An Improved Volumetric Method for the Determination of Hydrogen Sulphide and Soluble Sulphides. J. A. Kitchener, A. Liberman, and D. A. Spratt. (*Analyst*, 1951, **76**, Sept., 509–515). The use of alkaline sodium hypochlorite as a combined absorbing and oxidizing agent has been investigated. It offers many advantages over the usual iodometric method of determining hydrogen sulphide or sulphur in iron and steel. The reagent is stable to boiling and gives quantitative oxidation of sulphide to sulphate. The recommended method gives results correct to within 0·3% of the sulphur content.

Determination in Flue Dust, Coal, and Coke. H. J. Cluley. (*Analyst*, 1951, **76**, Sept., 530–535). The author's absorptiometric method for determining germanium with phenylfluorone has been applied to the analysis of flue dusts. The high sensitivity of the method permits the use of 0·1-g. samples, and this quickens decomposition of the sample in the sodium carbonate fusion. The procedure has also been applied to the determination of germanium in coal or coke. The sample is decomposed by a procedure similar to the Eschka method for the determination of sulphur in coal, or else by combustion in a bomb calorimeter. Samples of coal and coke contained 7 to 12 p.p.m. of germanium.—J. B. B.

HISTORICAL

A Tudor Furnace in Waterdown Forest. H. R. Schubert. (*J. Iron Steel Inst.*, 1951, **169**, Nov., 241–242).

A Romano-British Firedog. H. R. Schubert. (*J. Iron Steel Inst.*, 1951, **170**, Jan., 25). [This issue].

Creators of the Steel Age—III : Sir Charles William Siemens, F.R.S. R. Edwards. (*Brit. Steelmaker*, 1951, **17**, Aug., 414–421, 425). This article describes the contributions to steelmaking of Sir Charles Williams Siemens, F.R.S. His development of the open-hearth furnace for steelmaking is described, and the adoption of the process after its initial failures is discussed.—G. F.

Dud Dudley, Iron Master of the Seventeenth Century. E. N. Simons. (*Far and Wide*, 1951, **18**, 25–27). Dud Dudley claims to have manufactured successfully in 1619 both wrought and cast iron with the aid of pit-coal instead of charcoal for the first time. A brief account of his life is given.—T. E. D.

Moulding and Founding Technique in the Pre-Christian Era. E. Piwowarsky. (*Giesserei*, 1951, **38**, Oct. 18, 548–556). This is a review of knowledge on the working of gold, copper, bronze, iron, and cast iron by the peoples of the Near East, Egypt, and China. There are 41 illustrations of archaeological objects.

J. G. W

ECONOMICS AND STATISTICS

Difficulties of Swedish Metallurgy. (*Usine Nouvelle*, 1951, **7**, Sept. 6, 23). Shortages of fuel, raw materials, and skilled labour exist in Sweden. Iron ore is abundant but 200,000 tons of scrap are required per year and lack of tungsten, chromium, and molybdenum handicap production of alloy steels. The sponge-iron processes are more economical in coke than the blast-furnace. The output of iron and steel is to be 2,000,000 tons in 1955.—A. G.

Economics of Purchased Power *vs.* Plant Generated Power in the Pittsburgh District. W. B. Skinkle. (*Iron and Steel Eng.*, 1951, **28**, Aug., 85–97). This paper compares the economics of purchasing electrical energy from a public utility company with those derived from a coal-fired generating plant of the same capacity constructed for and maintained by the works. The author concludes that, on the whole, it would not be economical to install a coal-fired power station in competition with the power rates considered, unless the works has surplus power as a by-product.—M. D. J. B.

Economic State of the Foundry Industry with Particular Reference to the Supply of Raw Materials. H. Burkart. (*Giesserei*, 1951, **38**, Sept. 30, 453–459). The author believes that the capacity of German foundries (265,000 tons of castings per month) is excessive. Foundries should concentrate on modernizing plant and reducing costs.—R. A. R.

How to Overcome Materials Shortages. H. R. Clauser. (*Mat. Methods*, 1951, **34**, July, 89–112H). This comprehensive article is intended to help enginers and designers by bringing together in one place the following information: Ways of overcoming materials shortages; suggestions on conserving or replacing specific scarce materials; where and how alternative materials can be used; and case histories describing how some companies are overcoming the shortages problem. There is a table listing specific alternative materials for specific products.—P. M. C.

MISCELLANEOUS

Isotopes Techniques Conference : Application of Radio-Isotopes to Metallurgical Study. (*Iron Coal Trades Rev.*, 1951, **163**, July 27, 203–204). In this article, brief summaries are given of papers dealing with the application of radioisotopes to metallurgical study, which were read before an international conference on isotope techniques arranged by the Atomic Energy Research Establishment and the Medical Research Council in July 1951.—G. F.

Simple Methods for Calculating the Weights of Rotating Members. P. Sahmel. (Giesserei, 1951, **38**, June 28, 304–306). A table of the weights of steel rounds and conversion factors for other common shapes of bar and other metals are presented. For machine members of more complicated cross-section a special slide rule can be employed to calculate the weight rapidly. The theory and application of this slide rule are explained.—R. A. R.

Boiler-Water-Treatment Manual for Federal-Plant Operators. L. Goldman. (*U.S. Bur. Mines*, 1951, Handbook 5). The manual deals with 'internal' boiler-water-treatment and gives the basic information needed for adding chemicals.

New Facilities for Stocking and Shipping Pipe at Lorain Works. C. C. Wales. (*Iron Steel Eng.*, 1951, **28**, Aug., 71–75). This paper describes the assembly, stocking, and preparation for dispatch of the products of the Lorain works of the National Tube Co., with diagrams.—M. D. J. B.

Pollution Control Program for Ohio. B. M. McDill. (*Iron Steel Eng.*, 1951, **28**, Aug., 101–107). The author discusses the developments incidental to recent legislation, and the organization for water-pollution control, and suggests a programme.—M. D. J. B.

A High Frequency Induction Heating Equipment for Physical Metallurgy Research. R. Gabel. (*Met. Vick. Gaz.*, 1950, **23**, Sept.–Oct., 249–251). The Associated Electrical Industries Research Laboratory has installed a high-frequency induction furnace. The motor-generator set, which provides a single-phase supply at 10,000 cycles/sec., the condenser, and furnace and its operation are described.—R. A. R.

A Suspended Graphite-Spiral Furnace. M. Balicki, E. G. Kendall, and W. H. Orthman. (*Metal Progress*, 1951, **60**, Aug., 72–74). This laboratory furnace for research work can operate at above 2200° C. The design involves only one rigid joint in the graphite element. Details are given of its construction and operation.—E. T. L.

The Study of Dusts in Industrial Atmospheres. I—Determination of the Particle Count. II—The Koniometer and Jet Sampling Instruments. III—The Impinger and Cascade Impactor. IV—Determination of Mass Concentration. V—. The Determination of Mass Concentration by the Volatile Filter Method. VI—Photoelectric Apparatus and Apparatus for the Collection of Large Samples. P. F. Holt. (*Metallurgia*, 1951, **43**, Mar., 151–152; Apr., 203–204; May, 258–259; June, 309–310; **44**, July, 52–54; Aug., 108–110). In the first part the author describes the 'thermal precipitator,' which gives the most accurate results. It involves precipitating the dust round an electrically heated wire on to microscope cover slips, which are then observed under a microscope, enabling the dust particles to be counted. In view of the delicacy of the thermal precipitator for dust concentration measurement, the koniometer, described in Part II, is used widely. In this the dust is deposited on to a glass plate for subsequent microscopical investigation. The Owen jet apparatus collects the dust, not on a glycerine coated plate, but on a clean plate after the dust has been made damp. In Part III the author considers the impinger and cascade impactor and in Part IV the determination of mass concentration is dealt with. In Part V there is a description of the

naphthalene filter method, and a consideration of particle-size distribution in relation to mass concentration. Part VI deals with photoelectric apparatus for measuring dust concentrations.—E. T. L.

Punched-Card Method of Evaluation of Technical and Industrial Records. O. Hengstenberg. (*Stahl u. Eisen*, 1951, **71**, July 19, 776–781). Modern Hollerith punched-card machines are briefly described and the work of an evaluating department is outlined. (17 references).—A. G.

The New Central Laboratory of Höganäs-Billesholms AB. G. Lindblad and H. Zimdahl. (*IVA*, 1949, **20**, 4, 139–157). [In Swedish]. The layout and equipment of the new laboratories of the above company are described.—R. A. R.

Trends in Industrial Instrumentation. S. L. Barron. (*J. B'ham. Met. Soc.*, 1950, **30**, Dec., 127–129). Many newly developed industrial instruments operate from electronic devices and servo-mechanisms. The advantages and disadvantages of such systems are presented and discussed.—J. B. B.

Electronic Instrumentation in Industry. S. F. Smith. (*J. Soc. Eng.*, 1951, **42**, July–Sept., 119–135). This paper deals with the technical outlines of some of the newer pieces of electronic equipment. Particular reference is made to the detection and measurement of vibratory motion; the cathode-ray oscilloscope, vibration pick-up, and calibration unit are described. The high-powered stroboscope is also outlined in connection with the same problem.—T. E. D.

Apparatus for Preparation of Metals with an Exactly Known Content of Impurities. J. D. Fast. (*Philips Tech. Rev.*, 1950, **11**, Feb., 241–244). A description is given of an induction-heated vacuum melting apparatus (2 kg. capacity) in which impurities can be added to very pure carbonyl iron or mild steel in precisely determined quantities. The preparation of iron with less than 0·001% impurities is described; to this may be added oxygen, carbon, or other solids, either together or separately. Nitrogen-containing iron cannot be obtained free from porosity or in quantities exceeding 1 kg. unless oxygen or carbon is also present.—J. G. W.

Lot Inspection by Sampling. H. C. Hamaker. (*Philips Tech. Rev.*, 1949, **11**, Dec., 176–182). The quality of an inspection lot of mass-produced articles may often be judged by means of a sample, the simplest method being that of single sampling characterized by a sample size n_0 and an acceptance number c_0 (number of rejects allowed in the sample). By plotting the probability of acceptance as a function of the percentage defective in the inspection lot the 'operating characteristic' is obtained which is shown to represent the practical performance of a sampling method in a satisfactory manner. The principles of double and sequential sampling are next discussed, procedures which require a smaller number of observations than single sampling. It is indicated how the relative merits of the two methods may be evaluated. Finally the factors, mainly economic, determining the choice of a particular sampling plan are considered.—J. B. B.

Preventive Maintenance Procedures. J. B. Whitlock. (*Amer. Iron Steel Inst.: Blast Furn. Steel Plant*, 1951, **39**, June, 671–673, 678). The maintenance system as operated by the Armco Steel Corp. is discussed. The four procedures at the basis of the system are: An inspection system of maintenance, research on failures, lubrication of equipment, and training of maintenance personnel.—J. P. S.

BOOK NOTICES

KOHLHASE, F. "*Hand und Tabellenbuch für die Drahtindustrie, das Drahtgewerbe und dessen Nebenzweige.*" 8vo. Hamm (Westf.) 1950. Emil Griebsch Verlag.

Kohlhase's handbook is, to the reviewer's knowledge, the first of its kind to be addressed to the technician in the iron and steel wire industry. For this reason it deserves especial notice, even though it is bound to be of limited value outside Germany, on account of difference in units and specifications.

The book is in its first edition and, as no doubt has been the case with other well-known engineering handbooks, will have to undergo many changes before it may qualify for the status of the 'technician's bible.' Superficially, it bears a close resemblance to standard engineering handbooks: it is divided into sections and equipped with a thumb-index, and it contains many of the customary numerical tables. This, however, is where the resemblance ends. A closer study reveals that the subject matter is almost entirely confined to specifications of wires and wire products, and of mechanical tests, reproduced from German standards (DIN and German State Railways), and to lists of trade definitions of wire qualities. The rest consists of numerical tables. Some of these are useful, *e.g.*, those relating wire diameter, ultimate tensile stress, and breaking load. Some are, in the reviewer's opinion, a waste of valuable space, *e.g.*, tables of squares, square roots, and areas of various rectangles; many of these numbers may be calculated in one's head, or on the slide rule. Finally, some tables, by any standard, are curiosities, *e.g.*, the table in which, among other things, one is told the specific gravity of coffee and of clover. The subject index is totally inadequate, and the ordering of the subject matter leaves much to be desired. For instance, a paragraph on liquid wire-drawing lubricants was eventually discovered under 'chemical and physical tables.' There is no information on wire-drawing machinery and the horse-powers required, on die sizes, die grinding and polishing, on cleaning plant and processes, on heat-treatment, and many other topics of vital interest and importance to the wire-manufacturing technician. In fact, with the exception of a table listing recommended draftings, machine speeds, and die angles for the production of selected qualities of high-tensile wire, and of a short list of prescriptions for fluid lubricants, the book contains no data which are not already readily accessible to the technician in the wire industry.

These criticisms would not be worth stating in detail were it not for the fact that an informative handbook is badly needed in the wire industry. It is not surprising that Kohlhase's book, being the first in the field, falls short of the mark—its virtue is that it has been written. It is to be hoped that in later editions present shortcomings will be eliminated; some of the numerical tables might well be omitted, the descriptive matter should be greatly expanded, and a proper subject index should be provided. In the meantime the book may certainly be recommended to English technicians as a handy and up-to-date source on German wire specifications.—J. G. WISTREICH

LEWIS, D. M. "*Magnetic and Electrical Methods of Non-Destructive Testing.*" 8vo, pp. 242. Illustrated. London, 1951: George Allen and Unwin, Ltd. (Price 35*s.*)

During the course of its activities, the Magnetic and Electrical Methods Sub-Committee of the British Iron and Steel Research Association considered that sufficient work on magnetic and electrical non-destructive testing was already reported in the literature to justify collection into a review. The result we have in the present volume by D. M. Lewis.

In his introduction the author classifies non-destructive testing into purely mechanical, optical, radiological (X-rays and gamma rays), acoustic (including supersonic), and lastly, magnetic and electrical methods with which we are concerned at present. He points out that some techniques, such as X-ray, may involve electrical generation, but the actual search medium is not of an electrical nature; further, that quantitative determination of magnetic and electrical properties falls outside the field.

The book is divided into four main parts. The first and largest part is entitled 'Magnetic Particle Testing,' and covers the various aspects of the detection of defects by this method. The section concludes with a chapter on typical testing procedures. In the second part, direct-current search coil, alternating current, and resistance methods for crack detection are described. Then in Part 3 we have a short treatment of magnetic and electrical methods of measuring plate and coating thickness.

Part 4 describes magnetic sorting, electronic sorting and testing, the determination of the carbon content of steel by physical techniques, and tribo- and thermo-electric sorting methods. How many metallurgists could define the tribo-electric effect? It is associated with the age-old experiment of rubbing amber with fur, in that, when two dissimilar materials are rubbed together, an E.M.F. is generated, ranging from a fraction of a millivolt to several millivolts. The possibilities of using this effect for sorting metals will be appreciated.

A large amount of work has gone into the preparation of

this report. Not unnaturally the majority of examples refer to steel although a number of non-ferrous applications are described. The matter is presented in a clear and direct manner without mathematical analysis, although references are given to this treatment. The average technical man should have no difficulty in following the text. There is a large bibliography of text references at the end of the book as well as three useful appendices. The volume is well produced and it is illustrated with numerous and very clear line drawings and photographs. However, one can hardly subscribe to the publisher's description of the book as a work of reference ; it is rather, as the author terms it, a review.—A. R. BAILEY

TIBBENHAM, L. J. "*Encyclopaedia of Oxy-Acetylene Welding.*" 8vo, pp. v + 73. Illustrated. London, 1951 : Sir Isaac Pitman and Sons Ltd., (Price 10*s.* 6*d.*)

The use of the word ' Encyclopaedia ' in the title of this book is misleading because it is essentially a glossary of terms encountered in oxy-acetylene welding, dealt with in a mere 70 pages. It sets out to cover the more practical aspects of the subject and this has been done by treating each of the more common terms encountered in oxy-acetylene welding alphabetically.

This book should appeal primarily to students and executives whose occupation is not connected intimately with welding but who have occasionally to refer to that subject. Unlike many other books on welding which have been written and published, the sketches and photographs are particularly clear and leave very little to the imagination. Emphasis has been placed on the use of low-temperature welding using the bronze type of filler metal, and subjects such as the welding of mild-steel sheet and pipes, and the ' arc on oxy technique ' have either been omitted or dealt with too briefly.

It is perhaps surprising to find reference to oxy-acetylene cutting in a book whose title leads one to expect welding matters only to be discussed, and disappointing to find recent developments such as solid-phase welding completely omitted. Again in such a short book the use of space for the reproduction of ordinary conversion tables might have been avoided and more space devoted to the subject under consideration. There would appear to be no reason whatever for including a definition of ' drawing the arc,' a procedure never to be encountered in oxy-acetylene welding.

A regrettable feature of the book is that it is not completely free from commercial bias and two or three of the tables refer to the proprietary products of one manufacturer where equivalents are available from others. For instance, data on the fusion welding of mild steel giving the approximate consumption of filler rod refer not to low carbon mild-steel filler rods, but to the proprietary product of one manufacturer of filler rods. Similarly, a list of the melting points of metals includes welding rods under the proprietary name, alternatives no doubt being obtainable from other manufacturers. In this same table carbon may well have been omitted since its inclusion implies that carbon is regarded by the author as a metal.

The wide practical experience and knowledge of the author, acknowledged as it is in many spheres of oxy-acetylene welding, is not adequately reflected in this book, and it is to be hoped that a second edition will pay more attention to detail and avoid commercial bias.

A. J. HIPPERSON

NEW PUBLICATIONS

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS. "*Basic Open-Hearth Steelmaking.*" By the Physical Chemistry of Steelmaking Committee, Iron and Steel Division, A.I.M.E. Second edition completely revised and enlarged. 8vo, pp. xix + 940. Illustrated. New York, 1951 : The Institute. (Price 60*s.*)

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS. "*The Solidification of Metals and Alloys.*" A Symposium held by the Institute of Metals Division, A.I.M.E. Feb. 12, 1950. 8vo, pp. v + 73. Illustrated. New York, 1951 : The Institute. (Price 22*s.* 6*d.*)

AMERICAN IRON AND STEEL INSTITUTE. "*Directory of Iron and Steel Works of the United States and Canada.*" Twenty-Sixth Edition. 8vo, pp. xix + 534. New York, 1951 : The Institute.

BIJVOET, J. M., N. H. KOLKMEYER, and CAROLINE H. MACGILLAVRY. "*X-Ray Analysis of Crystals.*" 8vo, pp. xii + 304. Illustrated. London, 1951 : Butterworth's Scientific Publications. (Price 50*s.*)

BRITISH ALUMINIUM CO. LTD. "*Aluminium in the Chemical and Food Industries.*" La 8vo, pp. 149. Illustrated. London, 1951 : The Company.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION. "*The Instrumentation of Open-Hearth Furnaces.*" 8vo, pp. xiv + 159. Illustrated. London, 1951 : George Allen and Unwin, Ltd. (Price 30*s.*)

BRITISH STANDARDS INSTITUTION. B.S. 1121 : 22 : 1951. "*Methods for the Analysis of Iron and Steel.*" Part 22. "*Tin in Ferro-Tungsten and Tungsten Metal.*" 8vo, pp. 7. London : The Institution. (Price 1*s.*)

BRITISH STANDARDS INSTITUTION. B.S. 1775 : 1951. "*Steel Tubes for Mechanical, Structural and General Engineering Purposes.*" 8vo, pp. 26. London : The Institution. (Price 3*s.*)

COSSLETT, V. E. "*Practical Electron Microscopy.*" 8vo, pp. xiii + 299. Illustrated. London, 1951 : Butterworth's Scientific Publications. (Price 35*s.*)

FIELD, S. and A. D. WEILL. "*Electro-Plating. A Survey of Modern Practice.*" Sixth Edition. London : Sir Isaac Pitman and Sons Ltd. (Price 20*s.*)

"*Gmelins Handbuch der anorganischen Chemie.*" 8. Auflage. System Nummer 41. "*Titan.*" La 8vo, pp. xxii + 481. Weinheim/Bergstrasse, 1951 : Verlag Chemie G.m.b.H. (Price DM 113.–)

GROUPEMENT POUR L'AVANCEMENT DES MÉTHODES SPECTROGRAPHIQUES DES PRODUITS METALLURGIQUES. "*Colloque International de Spectrographie de Strasbourge,*" tenu à l'Université de Strasbourg les 12, 13 et 14 Octobre, 1950. 8vo, pp. 208. Illustrated. Paris, 1951.

HAUFE, W. "*Schnellstähle und ihre Wärmebehandlung.*" 8vo, pp. 276. Illustrated. Munich, 1951 : Carl Hanser Verlag. (Price DM 29.–)

HENRY, N. F. M., H. LIPSON, and W. A. WOOSTER. "*The Interpretation of X-Ray Diffraction Photographs.*" 4to, pp. ix + 258. Illustrated. London, 1951 : Macmillan and Co., Ltd. (Price 42*s.*)

INSTITUTE OF PHYSICS. "*Vacuum Physics.*" A symposium held by the Midland Branch of The Institute of Physics in Birmingham on 27 and 28 June, 1950. Journal of Scientific Instruments, Supplement No. 1. 4to, pp. 80. Illustrated. London, 1951. The Institute of Physics. (Price 15*s.*)

IRON AND STEEL INSTITUTE. Special Report No. 44. "*Surface Defects in Ingots and their Products (Recommended Definitions).*" Prepared by the Ingot Surface Defects Sub-Committee (Steel Making Division) of the British Iron and Steel Research Association. 4to, pp. 50. Illustrated. London, 1951 : The Institute. (Price 25*s.* to non-members ; 15*s.* to members)

LIPSETT, C. H. "*Industrial Wastes, Their Conservation and Utilization.*" Pp. 328. New York, 1951 : Atlas Publishing, Co. (Price $5)

OLSEN, G. A. "*Strength of Materials.*" 8vo, pp. vi + 442. Illustrated. London, 1951 : George Allen and Unwin, Ltd. (Price 32*s.* 6*d.*)

RAPATZ, F. "*Die Edelstähle.*" 4. Aufl. 8vo, pp. v + 730. Illustrated. Berlin, Göttingen, Heidelberg, 1951 : Springer-Verlag. (Price DM 49.50)

SPELLER, F. N. "*Corrosion, Causes and Prevention.*" 3rd Edition. 8vo, pp. xiii + 686. New York, 1951 : McGraw-Hill Book Co., Inc. (Price $10)

THEWS, E. R. "*Metallurgische Verarbeitung von Altmetallen und Rückständen.*" Band II. "*Altrotmetalle.*" 8vo, pp. 290. Illustrated. Munich, 1951 : Carl Hanser Verlag. (Price DM 31.50)

WERNICK, S. "*Electrolytic Polishing and Bright Plating of Metals.*" Second edition. London : Alvin Redman, Ltd. (Price 30*s.*)

SAMUEL THOMSON

SAMUEL THOMSON, Director of Messrs. Colvilles Limited, was born at Kippen, Stirlingshire, and was educated at Kippen Public School and at Stirling High School. In 1906 he joined the staff of Messrs. David Colville and Sons, Limited, Dalzell Works, and received a general training in the Rolling Mills and Sales Departments.

In 1916 Mr. Thomson was appointed Chief of the Iron Works Mills Department at Dalzell Works, becoming Bar Mills Manager in 1921, Mills Manager in 1929, and Assistant to the Works Manager in 1934. Three years later he was appointed General Manager of Messrs. Colvilles associated company, The Lanarkshire Steel Company, Limited, and was elected to the Board of that company in 1947. Later in the same year he became an Executive Director of Messrs. Colvilles Limited, and General Manager of Dalzell and Lanarkshire Works. Further promotion came in 1951, when Mr. Thomson became a Director of the parent Company. In addition to his official duties, he has always been greatly interested in works' social and welfare activities.

Mr. Thomson is Vice-President of the Iron and Steel Trades Employers' Association, and acted as Deputy Leader of the Iron and Steel Productivity Team which visited the United States in 1950. He is also a Member of Council of the British Iron and Steel Research Association and Vice-President of the West of Scotland Iron and Steel Institute. He became a Member of The Iron and Steel Institute in 1937 and was elected a Member of Council in 1951.

Samuel Thomson
Member of Council